THE RELATIONSHIPS BETWEEN PLANTS AND THE SOILS ON WHICH THEY GROW

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C O N T E N T S

INTRODUCTION

The opinion is now held that a stage has been reached in the study of the vegetation of British uplands when the most useful information can be obtained from intensive autecological work on the more important species (Hill Farm Research Second Report 1953). However, in the study of the soils of these regions and the relationship of the vegetation to them, much valuable information which is most quickly obtained from extensive survey, has still to be collected.

The best starting point for a study of soils or plant communities is the making of a map of their distributions. Before boundaries between the various classes or groups may be drawn a clear idea of the limits of each much have been formed in the surveyor's mind. During the course of such a survey many facts concerning the relationships between the soils, the vegetation and the topography come to light.

Section 1 of this thesis is a report of such a survey in the eastern Lammermuir Hills of East Lothian. This location was chosen because it forms a small compact area, relatively uncomplicated by great variation in rock formation, and where heath and moorland develop under a relatively warm, dry climate. Each soil type and vegetation type is described and its distribution on the area given. This is followed by a discussion of the relations between soils, plant communities and topography.

Before an account of the distribution of individual species can be attempted a more detailed type of study is necessary. To this end a statistical survey to yield botanical analyses of the vegetation on each soil type, was devised. Section 2 is devoted to the results of this survey. It begins with an account of some features of the soils. A discussion of the relations between soil types and plant communities confirms the findings of Section 1. Each of the more common species, some fifty-six in all, is treated separately, the data for its frequency in relation to soil type and reaction, loss on ignition and depth of topsoil being presented along with a discussion in the light of previous work. This is followed by the figures for species occurring in low frequencies. The report closes with a discussion of points arising from the accounts of the species.

Beginning as an extensive survey of soils and vegetation it developed into a semi-intensive study of the soil requirements of individual species. The many trends and limitations of tolerance brought out need to be more deeply studied and this report should form a basis for such autecological work.

Chapter I

REVIEW OF THE LITERATURE

Early studies and comments on vegetation

The relationship between soil and plant has interested men for a very long time. The study from a chemical point of view, beginning in the sixteenth and seventeenth centuries, has grown into the modern sciences of plant physiology and agricultural chemistry. The work of botanists studying natural vegetation and undisturbed soils started later and is less well known to agriculturalists.

Throughout the eighteenth and nineteenth centuries, when map-making made geography one of the greatest of the natural sciences and biology was dominated by taxonomy, it was natural that attempts should be made to produce maps showing the distribution of species. This began in Germany with Schow (1823) and was followed in Great Britain by the work of H.C. Watson (1832, 1836, 1847-59, 1873-74). Walters (1957) has reviewed the history of this branch of botany up to the present Distribution Maps Scheme.

De Candolle relates in his memoirs (1862) how, before 1810, he had conceived a scheme for mapping the topography, geology, soils, climate and plants of France. Unfortunately, due to political events, he was unable to carry it out but his ideas spread sufficiently to give his country, by the beginning of the twentieth century, the best vegetation maps in Europe.

Many of the earlier writers on the geography, or the agricultural conditions of Britain made brief references to vegetation and soils. A correspondent of the Farmer's Magazine (Anon 1803), describing the Lammermuir hills, speaks of hill tops being "of black mossy ground covered with heather while the lower slopes have more earth and are grassy". Wallace and Kinch (1884), in discussing the food of hill sheep, give for several plant species or communities, a description of the type of site on which they can be found. This reference to soil conditions, using phrases like "wet mossy soils", or "hard dry land", will be referred to here as "soil-site" descriptions.

The appearance of geological maps brought to the notice of botanists the fact that species may be confined to or excluded from land over particular rock types. Atkinson (1824), discussing the geographical distribution of plants in Yorkshire pointed out that the heaths <u>Calluna vulgaris</u> and <u>Erica spp</u>. were never to be found on the Chalk or Limestones while other plants were never found away from them. He gave lists of the species which were associated with certain soil types, based on physical characters such as texture. Similarly Baker and Nowell (1854) discussed the relations of a flora to topography, geology and soils and Baker (1863), introducing the concept of soil types based on the rock strata below, showed how, along with climate and topography, the rock-soil type could control plant distribution. In the Flora of West Yorkshire (1888) F.A. Lees gave lists of species characteristic of certain rock-soil types. Following upon this Peacock (1904) formulated a scheme for constructing a Rock-soil Flora by a card index system. The soil types were classified on the basis of information from the solid and drift geological maps and from observations of the area. The vegetation was correlated with the soils by means of the relative frequencies of the various species. Applying the method he found an explanation for the peculiar distribution of <u>Ballota nigra</u> in south-east England (Peacock 1909). As the system was cumbersome and difficult to understand it was never used by other workers.

<u>Vegetation maps accompanied by comments on the soil conditions</u>

Ecology focussed the attention of botanists on plant communities as the unit of study. Professor Charles Flahault produced in 1897 a map of France showing the principal forest communities and described how these reflected variation in climate and soils. At this time when the continent of North America was being rapidly colonised by farmers, the Government of the United States found the natural vegetation map of Merriam (1898) invaluable as a guide to the usefulness of land for prospective settlement in the western states. In countries where a similar situation obtains today, in Australia, New Guinea, Tanganyika, Rhodesia and Kenya, primary surveys are being conducted.

Robert Smith, who had been Flahault's pupil, returned to Britain determined to use his methods in the study of vegetation. His first article in 1899 showed the value of grouping plants by the communities to which they belonged, into associations, and his later study (1900a) showed that Flahault's use of forest tree associations could not be extended to the British Isles because of the disturbed nature of the vegetation following on long and intensive use of the land. With the classification evolved during this study he began to make maps of the vegetation of south and central Scotland, the first of which (1900b), covering the northern part of Midlothian, was published as a coloured sheet at a scale of half an inch to the mile, and accompanied by a descriptive article. This was followed by a sheet covering North Perthshire (Smith 1900c). One result of this work was a call for an official Botanical Survey similar to the Ordnance and Geological Surveys (Smith 1902a). W.G. Smith, a brother of Robert, was stimulated to carry out similar work in Yorkshire as a result of which two maps were published (Smith and Moss 1903, Smith and Rankin 1903). Two further maps were produced for two areas in Westmorland and Durham (Lewis 1904a,b). Robert Smith died in 1902 leaving two unfinished sheets which were later published by his brother. These covered Fife (Smith and Smith 1904) and Forfar (Smith and Smith 1905).

During the surveys Robert Smith accumulated a knowledge of the relations between his vegetation types and the soils which bore them. Much of it is published in the memoir accompanying his last map. Steep rocky land bore on the knolls bent-fescue grassland with *Ulex europaeus* and *Nardus* in the depressions. Moist soils with a peaty top bore *Agrostis-fescue* - *Nardus* grassland or *Nardus* - *Juncus squarrosus* or *Nardus* grassland with *Molinia*. This latter was often associated with a wet peaty topsoil and a clay subsoil. Continuous peat over a yellow or yellow brown subsoil with or without an iron pan carried a *Calluna* heath. *Calluna* was almost alone on sloping land or dry flat ridges, or accompanied by *Nardus* and *Juncus squarrosus* in wet hollows, or by *Erica tetralix* if the peat was deeper and wetter. *Eriophorum* spp. was dominant on areas of deep, very wet peat with slow drainage and high rainfall, but an improvement in the drainage led to the co-dominance of Calluna. Wet soils, high in organic matter, bore a vegetation of rushes or sedges. Smith also drew attention to the zonation of vegetation on the Ochils on which Nardus - Molinia grassland occupied the flat hill tops, Nardus the crest of the slopes, Bracken its upper part and Agrostis-fescue grassland the lower parts.

At this time, for most students, the term "soil" meant only the topsoil and the bulk of research work was concerned with its chemical nature. The Russian school of soil science was working on its own lines and its ideas did not become widely known in Europe for another twenty years. Although Smith, like Wallace and Kinch, had not separated soil characters from site characters he had paid attention to the subsoil and given a rough description of two types of profile, the podzol and the peaty gley. Apart from a few with a training in soil science, ecologists as a whole have continued up to the present day to describe soils in soil-site terms although they have given up the description of vegetation in terms of habitat characters (Tansley 1920).

In 1905 Pethybridge and Praeger published a coloured vegetation map of the district south of Dublin, which showed clearly the zonation of vegetation due to increasing altitude. Marcel Hardy (1906) produced a map of the vegetation of Scotland north of a line from Iona via Inveraray to Fife, showing a clear relation between plant life and climate. The book describing the map, which had been published in Paris the previous year, divided the country into east and west 'domains' and showed that Pine wood, Oak forest and heath occupied special places in relation to climate and geology (Hardy 1905). There is no reference to soils and the references to geology were confined to its influence on topography.

The first small scale map was that of Gaut (1904) who mapped the grasses in a pasture at a scale of 150 ft. per inch and related the variations to soil conditions on the basis of descriptions and chemical tests of two profile pits. The defect in this work was the assumption common at that time that soil remained the same over wide areas. This is probably the first ecological study in which an attempt was made to study soil and vegetation in a scientific rather than a descriptive manner. W.G. Smith's statement (1902b) that chemical methods were too inaccurate for ecological use at that time may have deterred other workers from attempting to use them. It is more likely that the inaccuracy was due to error in the sampling than in the method of analysis. The need for collection of several samples and for statistical treatment of the data was not appreciated at the time.

Woodhead (1906) drew maps on a scale of six inches and twenty-five inches to a mile to bring out facts about plants of the woodlands near Huddersfield. This brought home to ecologists the value of large scale maps in the study of small areas and particular problems.

The cost of printing coloured maps and the lack of Government support combined to put an end to the scheme for a Botanical Survey of Britain. The Royal Geographical Society published a map of Somerset (Moss 1907), two more came out in book form, "The Moorlands of North-east Yorkshire," (Elgee 1912), and "The Vegetation of the Peak District," (Moss 1913), and the Scottish Geographical Society printed a map of the Ben Armine district in Sutherland (Crampton and Macgregor 1919). All other published maps have been in black and white. Brown (1913) made a survey of the parish of Shotts in Lanarkshire showing the vegetation grouped into cultivated land, heath and moorland, coniferous woods and deciduous woods. The text gives excellent soil-site information for many hill plants and communities. In the same year a vegetation map of the heath association of Hindhead Common was published (Fritsch and Parker 1913) as a preliminary to later studies (Fritsch and Salisbury 1915, Fritsch 1927), which were mainly concerned with the influence of repeated burning upon the succession in the heath. A soil survey, carried out with the maps as a guide, related the chemical characters of the soil to the vegetation, but does not deal with soil profile characters (Haines 1926).

Donald Macpherson, who was killed in France in 1917, made several maps of the vegetation of the Moorfoot Hills while employed as field assistant by the Edinburgh and East of Scotland College of Agriculture. Some of his findings had been given in a lecture to the British Association (Macpherson and Smith 1915) and later a paper was published, illustrated by a map, giving the relationships of Nardus to other vegetation and with soil-site characters (Smith 1918).

As mapping was a popular exercise for students in ecology, Salisbury (1920) proposed a standard scheme for representing vegetation types by symbols in black and white. This would have been very good for small scale maps of wide regions, but could not cover the detailed variation met with in the large scaled survey of small areas.

From this time, as experimental ecology, succession, and the influence of environmental factors absorbed the attention of botanists few maps were published, and of those that were, most were illustrations for the description of particular places. In

Ireland maps were made by Duff (1929), by Armstrong, Calvert and Ingold (1929) and Armstrong, Ingold and Vean (1934), the two latter containing soil-site information for several hill plants.

For England a survey of the Longmynd in Shropshire contains a half inch per mile vegetation map and some descriptive and chemical information about the soils (Leach 1931). The memoir accompanying the grassland map of England and Wales gives the typical soil-site characters for each type of sward (Stapledon and Davies 1941). Stapledon (1936) had previously written a book on his survey of the waste lands of Wales in which he classified vegetation types on moorland grazings and discussed the factors, among them soil, which controlled the vegetation.

In Scotland Fenton (1933) mapped the plant communities of Boghall Glen, Midlothian, and showed its relationship with geology, soil acidity and soil moisture. Discussing a map of Lewis (Hardy 1919), Geddes (1936) showed how the vegetation of the island was strongly determined by the underlying soils and by topography. A survey of the land vegetation of Ailsa Craig is illustrated by a map (Vevers 1936). A vegetation map of Lorne, Knapdale and Kintyre forms part of an essay into the effect of biotic factors in replacing forest by bog in Western Scotland (Watson 1939). Some soil-site descriptions are given in a survey of the islands of Canna and Sanday, Inverness-shire, which includes a transect or profile of the islands showing the relationship of the vegetation to slope, aspect and exposure (Asprey 1947). The survey of the plant ecology of Barra shows the influence of the shell sand of the coast and the peat of the elevated central region in determining the island's vegetation (MacLeod 1948).

Vegetation studies with references to soil conditions

While the aim of much vegetation survey had been the production of maps showing the geographical distribution of plant associations, several studies not involving maps were undertaken. As maps proved expensive to produce and limited in value these now provide the majority of cases.

Describing the heaths of northern Germany, Graebner (1901) emphasised the importance of soil fertility, as measured by the concentration of mineral salts in solution in the soil water, in determining the composition of heath communities. He included a description of a podzol with thin iron pan and stated that it was the typical soil of the area. In an article dealing with Britain in general it was stressed that the distribution of heaths and heather moors was controlled not by altitude but by the oceanic climate and the presence of peaty soils poor in mineral salts (Smith 1902b).

In addition to his vegetation maps Moss (1902) produced a descriptive survey of the moors of south-west Yorkshire. Smith (1909), in an address to the Leeds Geological Society, describing the Cleveland Hills, stressed the influence of the underlying rock on the vegetation there. Rankin (1910) also commented upon the importance of soil factors in determining the type of vegetation inhabiting the peat moors of Lonsdale. The different grassland communities in Orkney were classified on a habitat basis, the soil-site characters often being included in the terms (Scarth 1911). The difference between stable, or climax, vegetation and migratory, or seral, vegetation and the importance of climate and topography in determining both soils and vegetation were discussed in a survey of the vegetation of Caithness (Crampton 1911).

In 1911 there appeared the volume "Types of British Vegetation" which emphasised the importance of soil as a master factor in the control of plant life (Tansley 1911). It was superseded in 1939 by a larger book containing much more detailed information, especially about soil relations (Tansley 1939).

A descriptive account of the sheepwalks of mid-Wales was given by Stapledon (1914). In describing the grasslands of Britain, Smith and Crampton (1914) stated that amongst other factors, soils could determine whether an area would bear grassland or heath. They also showed how the various grassland types were to be found on different soils. Farrow (1915) in his first article on the vegetation of Breckland gave a descriptive account of the vegetation type and described the typical soil profile found below this lowland heath.

Jefferies (1915) studying the ecology of Molinia showed the importance of soil conditions, especially moisture, to the plant. In surveys of part of Durham the importance of soil moisture was also made clear (Jeffreys 1916, 1917).

A useful summary of the soil-site data for many species and associations was given by Smith (1916) in his unpublished volume on "Heather and Heather burning". It was the accumulation of this type of information which gave rise to the belief that plants could be used to indicate soil conditions. The promotion of this view in forestry (Murray 1922) led to much disappointment and to its discredit, until it was shown that although single plants were not sound indicators, plant communities, taken along with other factors by trained personnel with a knowledge of the particular locality, could be of value as guides to forest practice (Fraser 1933, 1936, 1940, Muir and Fraser 1939, Gimingham 1949). On the other hand it has been found in Canada that single species give a clearer indication of climatic and soil conditions than communities (Moss 1944).

In the southern Pennine Hills the succession of vegetation from grassland to heath is controlled by soil factors, particularly moisture and the depth of raw humus (Adamson 1918). In Berkshire, plant communities and patterns of land settlement are correlated with the four geological strata underlying the county (Morris 1919). Patton (1925) surveyed the Tinto Hills, a group on acid felsite in the Southern Uplands of Scotland. The vegetation was classified in some detail but very little information on soils is given. Leach (1931) studying Lake District screes found that as the soils became fixed and mature a woodland vegetation was developed. Fenton (1939) describes a range of screes in various stages of stability and fixation on the Pentland and Moorfoot Hills of Midlothian. The heaths of Breckland were the subject of study in a series of papers the first of which dealt with the soils, climate and vegetation in a general way (Watt 1936). The fourth paper, dealing with soil conditions is discussed here in a later section. That drainage and the thickness of the peat layer in the soil are important factors in controlling moorland plants is brought out in the study of a bog in a Welsh valley (Davies 1944).

Some surveys have concentrated on one or a few aspects of the vegetation and its relation with its environment. The repeated burning of Harpenden Common has produced a succession of vegetation accompanied by variations in soil conditions, notably a decrease in organic matter and an increase in acidity as vegetation re-colonises burnt areas (Eden 1924). Summerhayes _et al_ (1924) and Summerhayes and Williams (1926) described the changes in the vegetation of two Surrey heaths, consequent upon the destruction of woodland and gave soil-site characters for the various communities. Benson and Blackwell (1926) also showed that different soil-sites were colonised by different species when tree felling left bare a lowland English heath. In a survey of a Welsh raised bog dealing mainly with the regeneration complex, the relationships of the major units of vegetation to the drainage of the peat were discovered (Godwin and Conway 1939). Beijerinck (1940) gives details of the soil preferences of _Calluna vulgaris_ and the conditions required before it may become a dominant plant. A survey of two Welsh mountains, one on basic and the other on acid rock, showed how the composition of the material from which the soils are derived can influence the plant communities present (Evans 1944). A study of Ringinglow bog near Sheffield is concerned with the history of the peat formation, and the relations of the present surface to atmospheric pollution, and the soil factors of pH, peat depth and water table level (Conway 1949). A summary of the main vegetation types on hill land in Britain, with information on their associated soil and site characteristics can be found in "Mountains and Moorlands" (Pearsall 1950).

Three papers on the effect of biotic factors in changing the vegetation of the hills of south-east and mid-east Scotland contain much information on the soil-site characters of many plant communities (Fenton 1951, 1952, 1953).

Soil maps with references to vegetation

A scheme for surveying the soils of England was put forward in 1683 by Martin Lister who proposed that the "various sorts of sands, clays and the mixture known as earth" should be shown on a map. Among his observations the writer makes note of the "turfy earth upon the moors and mountains which supports Erica and Heath". It was more than a hundred years before the work of the eighteenth century agricultural improvers provided a stimulus for more concentrated study of the soils. Several writers describing the agriculture of particular counties, for instance, Somerville in 1805 for East Lothian and Keith in 1811 for Aberdeenshire, provided maps showing the distribution of soils of different texture mainly in the places of arable cultivation. The hill areas were neglected or outlined as bearing moorish or turfy earths.

Although there was considerable study of soils and their relations with vegetation it was not until the studies of the Russian scientists, Dokutchajeff, Sibircef and Glinka, and the German Raman, as described by Ogg (1928), had been brought to western Europe that mapping had a reasonable unit on which to base a classification. Their contribution was to show that as the form of the soil profile was the result of all the factors impinging upon it, it was a natural part of the climate-soil-vegetation system and therefore the proper unit of study. The Soil Map of Europe (Stremme 1927) produced on this system shows East Lothian to possess brown podzolised soils in the lowlands and heath podzols on the hill ground. Only the freely drained soils were considered in its making, as poorly drained and skeletal soils were, in the Russian system, deemed to cut across the World belts or great soil groups. They were therefore termed intrazonal soils.

Glentworth (1944), applying a system of classification used in Canada, (Ellis 1932), to the soils of Aberdeenshire, showed that within the great soil groups it was possible to separate soils on the basis, firstly of the parent material from which they are derived and secondly the degree of drainage or moisture conditions. This classification has been used as a basis for the work of the Soil Survey of Scotland, three of whose memoirs have now been published (Glentworth 1954, Muir 1956, Mitchell and Jarvis 1956). In the two latter and in a separate article (Muir 1955) the main vegetation of each soil type is described.

Soil studies with references to vegetation

As long ago as 1921 Salisbury noted that the stratification of layers, that is, the profile, of soils varied according to the amount of leaching and weathering it had received and that the acidity and content of micro-organisms varied in the different layers. He was able to relate the variation to topography and the vegetation cover.

Several investigators took up the study of natural soils in Britain. The moorland podzols and deep peats of Yorkshire were examined by Jacks (1932). Heddle and Ogg (1933) in their experiments on the improvement of hill pastures in Midlothian made a preliminary survey of soil types and vegetation. Fraser (1933) studied moorlands in the West of Scotland in relation to the growth of forest trees, and gave much information about the vegetation. Studies of Teindland State Forest in Morayshire (Muir 1934), Drummond Hill (Muir 1935) in Perthshire in conjunction with a forest survey (Murray 1935) and the north-east of Scotland (Muir 1940) also supply notes on the vegetation. In his survey of Scottish soils, Ogg (1935) collected profile descriptions, chemical data and species lists for sites all over the country, including five different soil types from the Moorfoot Hills. The relationship of three podzolic soils to each other and to topography has been studied in the North of England (Crompton 1952). Information on soils from all over Europe, often with notes on the vegetation, is supplied in a recent book (Kubiena 1953).

Soil and vegetation surveys

Ecologists have tended to think of soils as factors in the distribution of plants rather than as natural objects in their own right. With the spread of Continental ideas and the publication of a booklet (Jacks 1934) on the close relation between soils, vegetation and climate on a world scale many botanists approached the subject with a changed outlook. Velten (1934), surveying the soils and permanent pastures of the Market Harborough area, found a direct relationship between soil type and soil fertility and that this had a strong influence upon the species composition of the pasture and its value from a grazier's point of view. Fraser (1936), mapping a small area in Aberdeenshire found a strong correlation between topography, soil type and vegetation. When trees were planted they grew at different rates on the various soil types. In the same region, maps were made of the soils and the vegetation by two men working separately on hill land given over to forestry. They found that the soil formation was determined by the climate, which varied over the area, the nature of the parent rock and the topography, and that the plant associations varied with the soils and each was confined to a small range of soil types (Muir and Fraser 1939). In a general article on the method of making, and use of, a vegetation-soil survey for the benefit of foresters, Fraser (1940) gave a guide to the use of plant communities as indicators of soil type and thus suitability for tree growth.

In the north-west Conway valley Hughes has made soil and vegetation surveys of the hill land (1949a) and the grassland plant communities (1949b) which show strong associations between soils and the distribution of plant species. Ballantyne conducted a preliminary survey of soil plant relations in Midlothian (1951) and a more intensive survey of five plant associations on the Cheviot Hills of Roxburghshire (1953).

The work of Watt (1940) on the chalky boulder clay of Cambridgeshire, of Balme (1953) on limestone slopes, Gorham (1953, 1954) on woods in England and

Ireland and of Dimbleby (1952a,b,c) will be referred to more fully in later sections dealing with soil profiles and soil organic matter.

Soil vegetation surveys have been made in many other countries, in Germany (Ellenburg 1951, Bennema 1953), in Holland (Westhoff 1955), Belgium (Leenheer 1950), Croatia (Juras 1953), Rhodesia (Trapnell et al 1947, Grantham 1955), Nigeria (Morison 1948), Tanganyika (Milne 1947), the Belgian Congo (Denisoff and Noirfalaise 1954), Ceylon (de Rosayro 1943), the New England region of the United States (Lawrence 1933), California (Retzer 1953, Weislander and Storie 1953), in Canada (Newton and Stobbe 1934, Hubbard 1950, Wilde and Leaf 1955) and in Australia (Williams 1955). They are often used for the study of particular problems or to discover the economic possibilities of a region as in a study of yellowing and checked growth of tree seedlings in Britain (Day 1948), as an aid to the geomorphologist in Germany (Mensching 1950), for the correct stocking of woodlands in Croatia (Gracanin 1950), as an aid to Colonial development in Central Africa (Grantham and Pilson 1954), as a guide to the productivity of prairieland (Weaver 1924) or semi-arid forest range (Weislander and Storie 1952) in America, or forest growth and possible succession in Canada (Wilde, Voigt and Pierce 1954), to classify land for its suitability for irrigation in Australia (Taylor

1950) and as a preliminary to opening new areas for development in the same land (Rur. Resch. CSIRO 1954).

The soil profile in relation to vegetation

Of all the literature dealing with the subject, both in Britain and abroad (Jacks 1934, Newton and Stobbe 1934, Morison *et al* 1948, Milne 1947, Juras 1953, Manshard and Weinmann 1952, Moss 1944, Wilde and Leaf 1955), only the work of Lawrence (1933) in New England shows no correlation between soil type, as indicated by the soil profile, and the plant associations of the area. It has been seen in the preceding sections that there is a large literature dealing with the soil relations of the plants inhabiting hill land in Britain, but only that which refers to profile types or from which the profile type can, with certainty, be identified is dealt with here.

Descriptions of soil profiles, identifiable as podzols with iron pan, and said to be the typical substratum of *Calluneta* are given for the north German heaths (Graebner 1901), the Forfar hills of Scotland (Smith 1904) and for Breckland in East Anglia (Farrow 1915). In studying the beechwoods of north Scotland it was found that a grassy undergrowth having affinities with heathland was to be found on podzolic soils and a herbaceous type related to the flora of damp oakwoods on brown earths or gleyed light loams

(Watt 1931). In the south Pennine woods Holcus mollis dominates the undergrowth over brown forest soils and Deschampsia flexuosa, Bracken and Vaccinium myrtillus over podzolic soils (Scurfield 1953). (Dimbleby 1952a,b,c) has shown that these two soil types are interchangeable in Britain depending on the woodland vegetation type which has colonised them.

Watt (1940) has investigated the changes occurring in the species composition of an Agrostis-fescue grassland as the soil below develops from a chalky boulder clay to a podzol. His findings are in good agreement with those derived from a study of a soil catena over limestone in Derbyshire (Balme 1953). The soils range from an immature rendzina at the top to a mature podzol at the bottom. The subsidiary species varied from those typical of chalk grassland at the top to a number of typical heath plants at the base. The total number of species fell with increasing podzolisation of the soil.

In the material given below, which has been extracted from a number of sources, the localities of the studies are, Northern Europe generally (Kubiena 1953), Great Britain generally (Pearsall 1950), the north-west Conway valley, Wales (Hughes 1949), the Yorkshire moors (Jacks 1934), Morayshire (Muir 1934), Aberdeenshire (Fraser 1936, Muir and Fraser 1940), Perthshire (Muir 1935), Ayrshire (Mitchell and Jarvis

1956), the Cheviot Hills, Roxburghshire (Ballantyne 1953, Muir 1955), the Pentland Hills, Midlothian (Heddle and Ogg 1933, Ballantyne 1951) and the Moorfoot Hills, Midlothian (Ogg 1935).

The Brown Forest Soil of low base status is mentioned in three drainage groups, excessively, freely, and imperfectly drained. The first group may carry a vegetation of heath grassland dominated by Deschampsia flexuosa (Pearsall 1950, Ballantyne 1953), a mixture of heath grasses or a Calluna - Erica cinerea association (Muir and Fraser 1939), or a mixed short grassland of Agrostis tenuis and Festuca rubra with D. flexuosa, Nardus and V. myrtillus (Heddle and Ogg 1933). The freely drained series may bear forest or a grass sward (Kubiena 1953), a range of grasslands from pure short Agrostis-fescue turf to Nardus - Juncus squarrosus (Pearsall 1950), or Agrostis-fescue with Nardus to Nardus grassland (Hughes 1949), Agrostis-fescue grassland (Muir and Fraser 1940, Mitchell and Jarvis 1956, Ballantyne 1951, Ogg 1935), Agrostis grassland (Ballantyne 1953), Agrostis-fescue with Bracken (Muir 1955), Agrostis-fescue with Nardus and various herbs, Galium hercynicum, Potentilla erecta, Viola riviniana (Heddle and Ogg 1933). The imperfectly drained series bears Bracken if over 9" deep (Pearsall 1950), Agrostis-fescue with Trifolium repens, Lathyrus pratensis and Ranunculus repens

(Mitchell and Jarvis 1956), Agrostis-fescue with many low ground grasses and herbs and T. repens (Heddle and Ogg 1933), Agrostis-fescue with Nardus (Ballantyne 1953) or Agrostis-fescue with Bracken (Muir 1935, Ballantyne 1951).

There are four types of Peaty Podzol, distinguished by the drainage class and the depth of the profile, particularly the layer of mor. The shallow driest group may bear Deschampsia flexuosa - Vaccinium myrtillus heath (Pearsall 1950), Agrostis-fescue grassland sometimes with Nardus stricta (Hughes 1949), Calluna, Erica tetralix and D. flexuosa (Fraser 1936), Heath grassland dominated by D. flexuosa with some Nardus and Calluna (Ballantyne 1953), Nardus - V. myrtillus (Heddle and Ogg 1933), or V. myrtillus heath (Ballantyne 1951). The normal soil may bear Calluna-Erica tetralix (Kubiena 1953), Calluna - V. myrtillus with Agrostis spp., Festuca ovina, Juncus squarrosus and Nardus (Pearsall 1950), Agrostis-fescue or Agrostis - Festuca - Nardus grassland (Hughes 1949), Calluna with a few higher plants and several mosses, Hypnum cupressiforme, Hylocomium schreberi, Dicranum scoparium and Plagiothecium undulatum (Muir 1934), Calluna with Erica tetralix, D. flexuosa and Potentilla erecta (Fraser 1936), Calluna with V. myrtillus and D. flexuosa (Muir and Fraser 1940), Calluna - V. myrtillus (Muir 1935), Calluna or Nardus dominant over V. myrtillus, D. flexuosa and H. cupressiforme (Mitchell and Jarvis 1956), Calluna heath (Ballantyne 1953), Calluna heath or Nardus grassland (Ballantyne 1951), Calluna heath with V. myrtillus, Nardus, D. flexuosa (Ogg 1935). The series with a deeper mor layer and a gleyed A_2 horizon carries Calluna - Erica tetralix heath (Kubiena 1953), Calluna - Nardus with Molinia caerulea and Juncus squarrosus (Pearsall 1950), Calluna with Nardus, Trichophorum caespitosum, Molinia caerulea, Erica tetralix and Eriophorum vaginatum (Jacks 1932), Calluna with Erica tetralix, Trichophorum caespitosum and Cladonia spp. (Muir 1934), Calluna with Erica tetralix, Polytrichum commune and Sphagnum spp. (Fraser 1936), Calluna - Nardus heath (Muir and Fraser 1939), V. myrtillus and Calluna (Muir 1935), Calluna - Nardus with T. caespitosum, Eriophorum vaginatum and Sphagnum spp. (Mitchell and Jarvis 1956), Calluna - Molinia with Juncus squarrosus and Polytrichum commune (Muir 1955). Peat over 15 inches deep bears Calluna - Eriophorum vaginatum with T. caespitosum or Molinia, or Molinia moor in eastern Britain (Pearsall 1950), Sphagnum, E. vaginatum often with Calluna, or Nardus heath with Juncus articulatus, Erica tetralix, or Molinia grassland (Hughes 1949), Calluna - Eriophorum vaginatum with Sphagnum spp. (Jacks 1932, Mitchell and Jarvis 1956), Calluna, Erica tetralix, Sphagnum (Muir

3 maps.
(2 in cardboard cylinder
alongside theses case
1 mounted on cardboard
in 4 pieces.)

1936), Calluna - E. vaginatum (Muir and Fraser 1939), Calluna with E. vaginatum and Nardus (Ballantyne 1953), E. vaginatum - Calluna (Muir 1955), E. vaginatum with Calluna, sedges and grasses (Ogg 1935).

Podzolic gley soils bear Nardus grassland sometimes with Juncus articulatus, or Calluna - Erica tetralix wet heath, sometimes with E. vaginatum and Carex spp. or Molinia grassland (Hughes 1949), Calluna - T. caespitosum (Muir 1934), Calluna - Nardus with E. vaginatum and J. articulatus (Muir and Fraser 1939), Mixed heath with Calluna, Nardus, E. vaginatum, Juncus effusus and often Molinia (Mitchell and Jarvis 1956), Molinia grassland (Ballantyne 1953), Molinia, T. caespitosum, Calluna (Muir 1955), Molinia - Nardus grassland (Ogg 1935).

Non-calcareous gleys may bear lush grassy vegetation (Kubiena 1953), an Agrostis-fescue grassland with many lowland species, Deschampsia calspitora and Juncus communis (Pearsall 1950), a mixed Nardus grassland with Juncus articulatus or a Molinia meadow (Hughes 1949), a grassland dominated by Juncus articulatus and containing many herbs including Ranunculus repens, Viola palustris, V. riviniana and Cirsium palustre (Fraser 1936), a grass meadow or grassy flush vegetation dominated often by Juncus spp. (Muir and Fraser 1939), an Agrostis-fescue grassland with Juncus effusus, J. acutiflora, D. caespitosa and

C. palustre (Mitchell and Jarvis 1956), Nardus grassland (Ballantyne 1951, 1953), Agrostis-fescue grassland with Holcus lanatus and Juncus spp. (Heddle and Ogg 1933).

If the drainage is very poor the vegetation may be a rushy grassland (Hughes 1949), Juncus communis dominant over Holcus lanatus, Anthoxanthum odoratum and many herbs (Fraser 1936), Agrostis-fescue mixed grassland with Juncus spp. (Muir and Fraser 1939), Juncus communis dominating a grassland of Agrostis canina, Anthoxanthum odoratum, D. caespitosa and Cirsium palustre (Mitchell and Jarvis 1956), Juncus communis grassland (Ballantyne 1951, Ogg 1935).

The soil reaction in relation to vegetation

Since the discovery in the early twenties of this century that the hydrogen-ion concentration is a useful measure of base status in any soil type and that plants appeared to inhabit soils of definite pH ranges, many studies correlating plant communities or the density and frequency of individual species have been carried out. The studies of Salisbury (1921), Rayner (1921), Atkins (1922), Slager (1923), Salisbury (1925), Haines (1926), Atkins and Fenton (1930), Leach (1931), Fraser (1933), Vevers (1936), Wilkinson (1945-46), Hora (1947), Conway (1949), Klapp (1951) and Manshard and Wienmann (1952) are concerned with the range of soil reaction on which individual species are found or at which a species attains its highest frequency or greatest development. The work of Haines (1926), Pearsall (1938, 1941), MacLeod (1948), Conway (1949) and Ballantyne (1953) give data on the comparative soil pH ranges of different heath and moorland plant communities. Eden (1924), Watt (1940) and Harley and Yemm (1942) have shown that soil pH may vary throughout the course of a sere and that it may influence the species composition.

In all these investigations the soils were sampled below the plants selected only and no account was taken of data from sites in which the species did not occur. This allows the frequency of distribution of the plants to be confused with the frequency of distribution of the soils. Using data collected from Danish grasslands and treated by Raunkaier's formation statistical method, Olsen (1925) was able to ascertain the range of soil pH for many plants and to establish the importance of hydrogen-ion concentration in the soil as a factor controlling plant distribution. As the result of an analysis of vegetation in Boghall Glen, Fenton (1933) provides a table of the frequencies of six species in relation to four soil pH classes showing definite trends in frequency. The work of Heddle and Ogg (1933 and 1936) brings out this in flushing acid grassland with base rich water.

Emmet and Ashby (1934) devised a statistical technique for sampling and analysing vegetation in order to study critical differences in the effect of soil factors on small groups of species. They used it to prove that the correlation of Bracken and Blaeberry with soil pH was only apparent and that between pH 4.7 and 6.2 both were distributed independent of that factor. Jowett and Scurfield (1949a) applied a more powerful statistical test to this data and established a causal relationship between soil pH and the distributions of both species. Applying this test to data from Pennine oakwoods they were able to show that while Holcus mollis becomes dominant on soils of relatively high pH (3.5 to 3.93) Deschampsia flexuosa dominates on soils of relatively low pH (3.33 to 3.65).

The problem of plants restricted to acid habitats, or basic habitats has occupied botanists since the time of Atkinson (1824). Observing the presence of some species on certain European mountain ranges and their absence from others, Bonnier (1879) attributed this to the chemical composition of the rocks, especially the concentration of bases. He described the plants found on basic rocks as "calcaire" and those absent from them as "calcifuge". Tansley (1917) studied the occurrence of two species of Galium on several soil types and decided that competition between them was involved in determining their ranges. Evans (1944) described the floras developed on different rocks of a Welsh mountain range. Hydrogen-ion concentration has been used as a convenient scale for measuring the degree of base saturation in the soil in several investigations of the problem (Pearsall and Wray 1927, Da Silva 1934, Holdgate 1955). The general conclusion is that calcifuges, whose distribution tend to follow that of soil pH, may be forced by competition to grow on acid soils while calcicoles are confined to soils of high pH by their high calcium requirements.

Pearsall (1926) has tried to define soil acidity in such a way that it does not become synonymous with other soil conditions such as base status, nitrogen content, or water relations. Small (1954) has pointed out that as soil pH is a very variable quantity, depending on a multitude of other factors it is not possible to pin down any exact measurements representing a plant's range of tolerance which is universally applicable. It is better to consider species as members of groups with varying degrees of tolerance to different ranges of soil pH. He divides natural plants into six such groups.

1. Acidiphilous - usually below pH 4.8
   e.g. Eriophorum vaginatum, Empetrum nigrum, Genista anglica and Rumex acetosella.

2. Acid tolerant - always below pH 7.0 and down to below pH 4.8
   (a) usually below pH 5.5, e.g. Calluna vulgaris, Cynosurus cristatus, Ranunculus bulbosus;

(b) up to above pH 5.5, e.g. Agrostis canina, A. tenuis, Deschampsia flexuosa, Erica spp., Eriophorum angustifolium, Rubus spp., Stellaria media, Ulex europaeus, Vaccinium spp.

3. Amphitolerant - from below pH 4.8 to above pH 7.0 e.g. Achillea millefolium, Agrostis stolonifera, Anemone nemorosa, Anthoxanthum odoratum, Carex nigra, Deschampsia caespitosa, Festuca ovina, F. rubra, Fragaria vesca, Geum rivale, Hieracium pilosella, Holcus lanatus, Luzula multiflora, L. pilosa, Molinia caerulea, Oxalis acetosella, Plantago lanceolata, Polygala vulgaris, Potentilla erecta, Ranunculus acris, Rumex acetosa, Succissa pratensis, Trifolium repens, Veronica chamaedrys.

4. Mesophilous - always above pH 4.8 and always below pH 7.2 e.g. Luzula campestris, Pedicularis palustris, Viola canina.

5. Alka-tolerant - only above pH 4.8 and above pH 7.0 up to pH 7.9 e.g. Briza media, Campanula rotundifolia, Dactylis glomerata, Festuca elatior, Geum urbanum, Helianthemum chamaecystis, Prunella vulgaris.

6. Alkaliphilous - usually above pH 7.0 up to pH 8.4 e.g. Galium aparine, Lotus corniculatus, Parnassia palustris, Pimpinella saxifraga.

Pearsall (1952), pointing out that from an ecologist's point of view the study of a single species is of less value than of widespread units of clearly defined and well established plant communities, devised a classification with four groups of soil pH ranges which were related to the type of organic matter in the upper horizons:

(1)	below pH 3.8	mor humus
(2)	pH 3.8 - pH 4.8	moder humus
(3)	pH 5.0 - pH 6.0	mull humus
(4)	pH 6.5 and over	mull humus

He avers that this system allows the worker to relate soil pH to base status and leaching, to water content, to soil metabolism and to the type of vegetation.

<u>Soil organic matter in relation to the vegetation</u>

The amount and nature of the organic matter present in a soil is dependent firstly upon the vegetation growing on that soil and secondly upon other factors affecting its mode of breakdown and rate of accumulation. Similarly the vegetation is dependent on the organic matter as the latter forms a large part of the colloid complex which provides a habitat for the roots and a source of mineral salts for nutrition. Over the whole field of ecology relatively few studies of the interrelations of the two are available and very few indeed refer to hill land. There are many references in general surveys to soil-site descriptions in which the upper soil layers receive attention but in most cases it is impossible to disentangle the factor of soil organic matter from other factors and to refer the information to modern terminology.

Some workers have attempted to correlate the proportion of organic matter present in a soil, expressed as percentage loss on ignition, with species distribution or community structure. The work of Crump (1933) and others who used his water humus ratio is founded on this. Haines (1926), Pearsall (1941) and Ballantyne (1951, 1953) give figures for different plant communities. The variation in organic matter content of heath podzols throughout burning subseres has been investigated by Eden (1924) and Haines (1926).

Smith (1918) describes how the erosion of hill peat and the subsequent deposition of the material provides a habitat for a variety of grassland types, mostly dominated by *Nardus stricta* or in a succession leading to *Nardus* grassland. In the thinner peat of a *Calluna* heath the same phenomenon occurs where a stream erodes its banks (Leach 1931).

The depth of the layer of raw humus has received notice since the paper by Wallace and Kinch (1884). Lewis (1904b) pointed out that two *Calluna* dominated communities existed, one corresponding to moor on "thick peat" and another corresponding to heath on "thin peat". Adamson (1918) showed that succession from *Agrostis-fescue* grassland through *Nardus* heath to *Callunetum* was accomplished by an increase in the depth of the layer of peaty organic matter. Davies (1944) noted that various communities occurred on soils with different depths of peat. In the heathy woodlands of western Ireland many moorland species show a distinct relationship in their frequency of occurrence with the relative depth of the layer of mor overlying the mineral soil (Gorham 1954). The form of a plant's root system has been shown to fit it for the exploitation of a particular range of depths of topsoils and soil water conditions (Heath and Luckwill 1938).

The work of Muller (1887) and Romel (1935) in differentiating between mull and mor set the standards by which most ecologists describe soil organic matter. Modern classifications follow the pattern established by Kubiena (1953) in distinguishing three types, mull, moder and mor. Undoubtedly many of the references to mull, in work previous to the publication of "Soils of Europe", really mean moders, as few true mulls exist on unforested hill land. Fraser (1933) recognises three types of mor or peat. The pseudo-fibrous material of Trichophorum moors, the fibrous peats of Calluna moors and the amorphous peat of Molinia grasslands. In a survey of Scottish mosses he shows that only the latter two can be found in south-eastern counties of Scotland (Robertson and Fraser 1935).

It has been shown that birch trees, by their high mineral requirement, can transform a mor horizon into a moder type (Dimbleby 1952a,c).

In an appendix to the soil survey of Ayrshire, Mitchell and Jarvis (1956) provide material from which can be extracted a rough correlation between soil organic matter and hill vegetation type. From this material it becomes apparent that soil organic matter is but one of the many interdependent factors which are given expression in the whole soil profile.

Soil moisture in relation to vegetation

That the importance of soil moisture as a factor in determining the distribution of plants was recognised by all the early surveyors is apparent from the high place given to the descriptive terms dry, damp, moist, wet and waterlogged in their characterisation of the habitat.

Jefferies (1915) found in moorland that, whereas the soils below *Nardus* grassland were only moderately wet those below *Molinia* were wetter and those below *Eriophorum* wetter still. *Eriophorum* moor developed when the soil was saturated with stagnant or very slowly moving water but *Molinia* required well aerated moving water. The water may be moving horizontally or vertically but as soon as it stops or slows down greatly other plants, particularly *Polytrichum commune*, invade the area (McVean 1952). Artificial drainage of a *Nardus* grassland brings about a reduction in the amount of *Nardus*, *Molinia* and *Juncus effusus* and an increase in the amount of *Deschampsia flexuosa*, *Festuca ovina*, *Calluna*, *Potentilla erecta* and *Galium hercynicum* (Jeffreys 1917). Rutter (1955) found that the size of *Molinia* tussocks increased as the water table approached the soil surface. In <u>Agrostis-fescue</u> grassland <u>Festuca ovina</u> tends to dominate on drier land and <u>Agrostis tenuis</u> on moister (Farrow 1917). Poel (1951) shows that Bracken cannot grow in waterlogged soils, its range being restricted by the need for a well aerated habitat. <u>Juncus effusus</u> needs a high water level for its seeds to germinate and the effect of competition from other plants is increased as the water table is lowered (Lazenby 1955). Olsen (1925) measured the water table at each site on the grassland and moorland on which he carried out his studies of the influence of soil reaction on plants, and allowed that it did affect the distribution of the various species but not enough to disturb his conclusions.

Jeffreys (1917), Godwin and Conway (1939) and Conway (1949) suggest that the annual fluctuation and particularly the winter water levels may affect the growth of most species. In the <u>Calluna</u> - <u>Molinia</u> - <u>Erica tetralix</u> heaths of Hampshire Rutter (1955) found that <u>Calluna</u> and <u>E. tetralix</u> succeeded with lower water tables showing little fluctuation, but higher water tables with greater fluctuation allowed <u>Molinia</u> to dominate.

It is not possible to measure accurately the water content of soils so that the figure means something in terms of the vegetation. Any figure is bound to reflect recent climatic conditions whatever standards are applied to the collection of the samples. The data obtained from the difference in weight between air dry and oven dry samples measure only water unavailable to the plant. The method adopted by Crump (1913) to measure the moisture status of peaty soils by the ratio of the water content to the loss on ignition of the sample is based on a figure of this type. Despite the articles by Johnson (1913) showing that the values obtained were those of a ratio of two entities with no common standard and that it is of no significance in the study of the soil, several workers (Jeffreys 1917, Haines 1926, Pearsall 1941 and Ballantyne 1953) have used it. Naturally, different plant communities have been shown to be associated with soils having different water humus ratios. The nature and amount of the organic matter is different in each soil type and determines the amount of water held by that soil. Each soil type thus possesses its own distinct water humus ratio. There is no reason why two totally unrelated soils should not have the same ratio. The studies are also open to the objections raised to pH correlations by Emett and Ashby (1935) that only samples occurring under specific vegetation types are being measured and nothing is known of the figures from other sites so that no causal relationship can be established.

Colvin and Eisenmerger (1942) have measured the water holding capacity of the A and B horizons of soils occurring under different species in the New England region of the United States and found some interesting differences between surface and deep-rooting types. Hubbard (1950) has used clay content as a measure of waterholding capacity in soils of fairly uniform organic matter content in vegetation studies in Saskatchewan. He shows that the frequencies of some species are correlated with the factor and that these may be used as indicators of moisture conditions.

Another approach to the question was made by Haines (1928). He measured the ability of several plants to transpire under low soil moisture conditions, and graded them according to their "drought resistivity", placing *Calluna* and *Pteridium* highest and *Vaccinium myrtillus* lowest.

In Britain with its wide diversity of soil parent materials and climatic regions, drainage or soil moisture condition serves to distinguish soil types and to relate them to each other as members of a catena or soil association (Glentworth 1944). Having regard to the difficulty of obtain quantitative data relevant to plant growth, the most convenient measure would appear to be that given by that character of the soil profile which varies in relation to soil moisture, the degree of gleying. This shows immediately the horizons affected, the degree to which they are affected and the range of any fluctuation. The drainage classes described by Glentworth and Dion (1950) present this factor in its relation to the other factors of soil formation.

Previous studies of hill vegetation or soil conditions in south-east Scotland

The land use of the region has been described in the Farmer's Magazine for 1803, by Somerville (1805), and by Snodgrass (1953).

General surveys of the vegetation have been made in the Edinburgh district (Smith 1900b), in Lanark (Brown 1913), in the Moorfoot Hills (Macpherson and Smith 1915), the Tinto Hills (Patton 1925) and the Pentland Hills (Fenton 1933, 1939).

The influence of biotic factors has been dealt with generally by Smith (1916) and Fenton (1951, 1952), for the Pentland and Moorfoot areas by Fenton (1937, 1940, 1949, 1951), for the Moorfoots by Hunter (1954a, b), and for the Cheviots by King (1955).

The soil types in the Moorfoots and Lammermuirs have been described by Ogg (1935) and those in the Border country by Muir (1956).

Information on the relationship between soils and vegetation in the Pentlands is given by Fenton (1933), Heddle and Ogg (1933, 1936) and Ballantyne (1951), in the Moorfoots by Smith (1918) and in the Cheviots by Ballantyne (1953), King (1955) and Muir (1956).

Chapter II

THE TOPOGRAPHY, CLIMATE, HISTORY AND LAND-USE OF THE EASTERN LAMMERMUIR HILLS

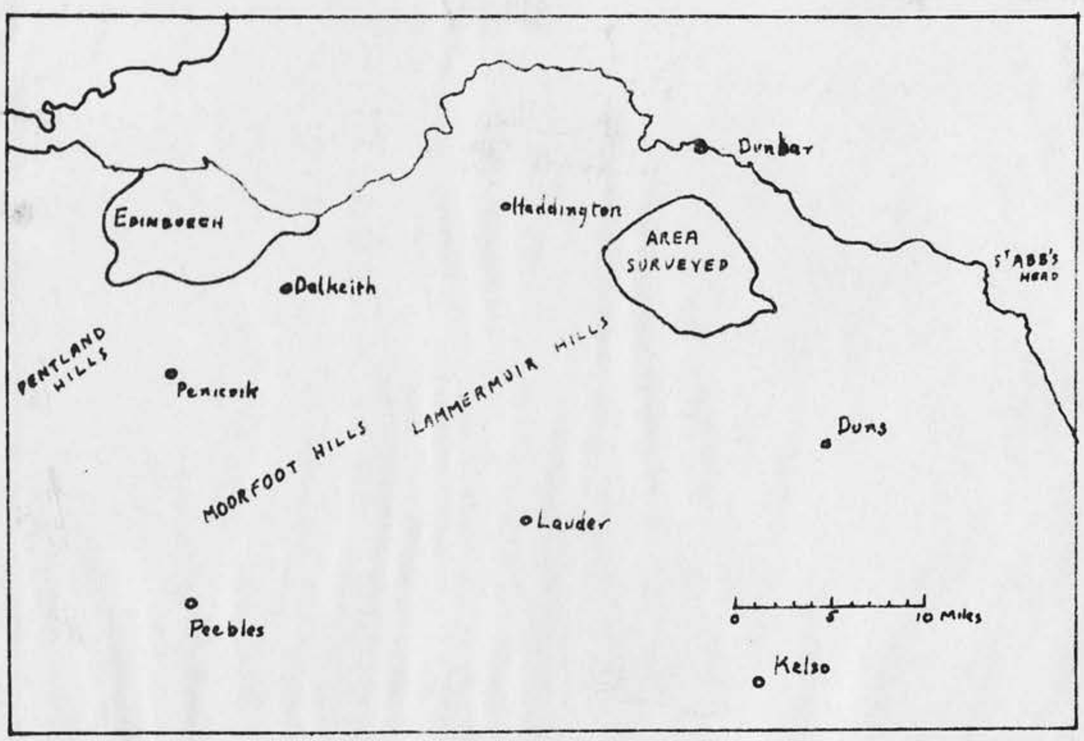
Location

The area which forms the subject of this study is the eastern part of the Lammermuir Hills in the County of East Lothian. The boundary very roughly follows the 800 ft. contour, occasionally descending to 650 ft. or ascending to 1,100 ft., along the head-dykes of the cultivated land from Thorter Reservoir (Map Reference 607.695) to Paits Hill (Ref. 747.673) from where it follows the road southwestwards and then the head dyke to Middle Monynut Farm (Ref. 723.648). Crossing the Monynut Water it runs along the head dyke by way of Inner Hill, Peat Law, Runshaw Rig, Crichness and Bothwell Hill to the Bell Wood (Ref. 672.633) thence northwestwards along the B6355 road to Thorter Reservoir. Parts of the parishes of Garvald, Whittingehame, Stenton, Spott, Innerwick and Oldhamstocks are included. (See Map 1 and Map 4 p. 45 .)

Topography

The Lammermuir Escarpment running from south-west to north-east rises steeply from the Lammermuir Foot Platform (Snodgrass 1953) to an average height of 1,150 ft., and is drained by tributaries of the

Whittingehame and Beil Water, the Spot Burn, the Thornton Burn and the Dry Burn. Running south-easterly from it are three ridges, the Spartleton Edge, the Middle Ridge and the Monynut Edge separated respectively by the valleys of the Whiteadder, Bothwell and Monynut Waters. The eastern slopes of the Monynut Edge drain into the North Sea by way of the Dunglass Burn and the Heriot Water while the southern part drains into the Eye Water. The ridges are fairly level along their tops at a height of 1,100 ft. to 1,200 ft. rising to form the more prominent hills of Clints Dod (1,307 ft.) and Spartleton (1,530 ft.) on the Spartleton Edge, Bransly Hill (1,301 ft.) and Peat Law (1,175 ft.) on the Middle Ridge while on the



MAP 4

South-east Scotland showing locality of the study.

Monynut Edge Wester Dod (1,345 ft.) is flanked by West Steel (1,275 ft.) and Heart Law (1,283 ft.).

The Lammermuir Edge is a steep escarpment and the ridges slope steeply up from 800 ft. to 1,200, the Monynut Edge being especially well dissected by small streams or dry valleys. The interior of the area, immediately to the south of the escarpment, forms a gently sloping saucer draining into the Bothwell Water.

Geology

The Lammermuir hills are part of a mountainous tableland, formed almost wholly by rocks of Silurian age, stretching from south of Dunbar across Scotland in a southwesterly direction into Wigtownshire. They were formed by the Southern Upland Fault which threw down the rock on its northern side so that the softer strata of Old Red Sandstone and Carboniferous age came to lie at the same level as those of Silurian age. These latter, having been hardened by the folding and compression of mountain building processes, were more resistant to erosion and thus came to stand up as hills along the line marking the change from one rock type to another (Clough 1910 and Pringle 1948).

Ordovician gritstones and shales are present on a small part at the north-west corner of the area.

Silurian rocks of the Llandovery series underly the larger part of the area on the western side. The strata are thin gritstones, greywackes, flagstones and shales of a grey to grey-brown colour which shatter along three cleavage planes to form sharp-angled rhombohedral fragments. The whole rock mass has been strongly folded along a north-east to south-west direction and the tops of the arches having been eroded off, the surface outcrops show a repetition of the same strata over wide areas.

At the eastern side an ancient valley in the Silurian landscape has been filled in under arid conditions by a conglomerate rock of Old Red Sandstone age. "This is composed of waste from the Silurian hills and contains fragments of all the rocks from which it has passed," (Geikie 1866), in this case entirely of fragments of Silurian rock about the size of those forming screes on hill slopes at the present time, cemented together by a very sparse ferruginous gritty paste.

Boulder-clay occurs over those parts of the area where the relief is moderate to level. It was deposited by ice during the Glacial period but it is not certain whether it was laid down only on the flatter land or over the whole area and later eroded off the more prominent places. None occurs on the steep slopes or the narrow ridges. That on the sites with moderate relief is of a fawn colour and a stony fine sandy loam to stony fine sandy silt texture, while in the hollows and level parts it becomes increasingly clay in texture, the stones become few and the colour, below the zone in which soil-forming processes act, a red brown.

The bottoms of the stream valleys bear a recent deposit of alluvium which varies in composition and texture from a coarse shingle through sand to stiff silty clay.

Peat occurs at heights of over 1,000 ft., mostly in hollows, the shoulders between hills, the level tops of high ridges and even in some cases the rounded summits of hills.

During the Ice Age the whole area was, for a considerable period, under a huge thickness of ice which, moving in a south-easterly direction, smoothed out the landscape to give it its present low relief. At a later stage the top of the Lammermuir plateau was clear of ice and the Midland Valley was filled with a glacier into which subsidiaries flowed from the hills. The meltwater channel between the steep cliff-like side of the ice and the escarpment tore out ravines and laid down spreads of sand and gravel thus being responsible for the more rugged topography along the northern edge.

Climate

While the County of East Lothian is well served by weather recording stations none are present within the area under discussion. Kingside School (779 ft.), immediately over the western boundary, lies in a hollow in the middle of the hills and may be taken as a representative station although low lying. Both it and Thorter Reservoir (725 ft.) have been collecting rainfall records only since 1948. The figures for these and other stations have been supplied to the writer by the Air Ministry Meteorological Office in Edinburgh from their records (Air Ministry 1954). In the absence of data from this area and its sparseness from other similar places, on most features of the weather, use has been made of the Climatological Atlas of the British Isles (H.M.S.O. 1952).

The temperature maps in the Climatological Atlas, from which the figures in Table 1 are taken, are based on records corrected to sea level. These have been recorrected to represent conditions at 1,200 ft. by subtracting $1^{\circ}F$ for every 300 ft. rise.

The figures show the normal seasonal rise and fall and that the climate is much cooler than in the adjacent lowlands. It is notable that the autumn months are relatively warm while the spring temperatures remain low well into the year. The coldest months are January and February and the warmest July and August. The average mean minimum temperature remains below freezing point from December to March.

Table 1. Mean Temperatures (from records between 1901 and 1930)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average Mean Daily Maximum	39	40	42	48	54	60	62.5	61.5	57	51.5	43	40	50
Average Mean Daily Minimum	30	29.5	31	33	38	43	46.5	46.5	42.5	37	32.5	30.5	36.5
Average Daily Mean	35	35	37	41	46	51	54	53.5	50	44.5	38	35.5	44

Table 2. Upland climates

Site	Elevation	Rainfall inches	Mean Temp. °F Jan.	June
Lowlands of S.E. Scotland				
North Berwick	118	25·1	39	55
Leith				
Western Highlands				
Loch Quoich	569	129	38	53
Fort William	1,000	83·6	36	52
Central Highlands				
Glen Gairn	1,100	34·4	34	51
Ben Venue	1,150	79·4	34	51
Southern Uplands				
Eskdalemuir	794	56·3	36	53
Redewater	1,100	46·7	34	52
Catcleugh	819	44·7	35	53
West Yorkshire				
Settle	1,328	67·3	36	52
Mudhope	1,000	43·4	37	54
Mossmoor	1,264	52·3	36	53
Lake District				
Styehead	1,070	146	38	53
Thirlmere	620	87	38	54
Wales				
Rhonnda	1,220	93·3	38	53
Afon Rheidol	1,060	73	38	53
S.W. England				
Dartmoor	1,074	67·9	40	55
Princetown	1,359	81·9	39	54

Examination of Table 1 provides the reason for the start of growth being delayed till June and ceasing in October, a four and a half month growing season.

The temperatures in the area are comparable with those recorded for the Eastern and Northern Highlands, and show a climate rather colder in winter and warmer in summer than that of the Welsh mountains or the Lake District.

The maps of the Climatological Atlas (Johnson 1952) show that there are 2-5 days per year with a maximum temperature of 32°F or less and 50 to 100 with a minimum temperature of 32°F or less. The corresponding figures for the occurrence of high temperatures show that they are about one tenth as frequent as in the English Midlands. The date for the first frost is given as October 15th and the last as May 1st, but these are respectively too late and too early for the more sheltered places.

According to the maps (H.M.S.O. 1952) the rainfall is lightest at about 25" around the edge of the range of hills and increases to about 40" in the interior a little to the west of Kingside. This feature is well brought out in Table 4,(p52).Although not well shown in Table 3, which is for five years and includes some rather abnormal figures, according to Snodgrass (1953) the driest months are from February to June and the wettest are July and August. September

Table 3. Average monthly rainfall at Kingside School 1949-53

Air Ministry Records (1954)

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rainfall in inches	2.01	2.26	2.27	2.82	1.70	2.20	2.85	3.25	3.40	3.35	5.35	3.45

Table 4. Actual Annual Rainfall for Several Stations

Air Ministry Records (1955)

Site	Position in relation to area		1941	42	43	44	45	46	47	48	49	50	51	52	53	54
Red-heugh	8 mls.E.	288'	29.52	19.86	22.42	27.86	28.70	30.98	28.64	34.11	22.06	25.81	32.47	24.84	19.50	32.12
Dunolly	3 mls.N.W.	532'											36.14	28.44	27.06	37.29
Thorter	½ ml. N.W.	725'	26.83	21.55	24.08	34.48	29.92	29.52	27.87	41.31	28.38	31.22	36.10	29.16	27.70	38.67
Lammer-loch	19 mls.S.W.	900'	29.52	25.66	26.44	34.54	31.48	29.79	26.47	37.59	34.61	27.46	35.36	27.26	27.82	42.81
Stob-sheil	10 mls.S.W.	950'	30.02	26.90	27.44	34.46	32.46	31.18	30.56	39.56	26.38	32.14	38.49	32.91	28.19	40.73
King-side	W. edge	779'									32.02	38.20	40.72	38.22	29.45	50.69

and the first half of October are usually dry but periodically have heavy showers. Months with over six inches rainfall are not infrequent in summer and months with under half an inch in spring. On the average there are 16.6 days with precipitation every month (H.M.S.O. 1952).

Rainfall in this area is less heavy and more sporadic than in most areas of moorland and heath.

Table 6. Occurrence of Snow
at 900 - 1,100 ft. (1912-1938)
(H.M.S.O. 1952)

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Year
No. of days in which snow fell	5	7	8	7	8	5	30 - 40
No. of days in which snow lay		3	5	5	5		20

Usually the road from Garvald through Kingside to Abbey St. Bathans is blocked by either heavy snowfalls or drifting snow from one to three weeks in each year. The Lammermuir hills are noted for their short but severe and sudden winter storms. The amount of snow received by the area is similar to that in the Lake District, rather less than in the Eastern Highlands and more than the Welsh Mountains.

Fog although frequent on the coast nearby is not prevalent, the hills being often in brilliant sunshine while the lowlands are blanketted. Mist, due to low cloud, is much more common at all times, but mostly in the first six months of the year.

Statistics from the Bell Rock, an island off the Estuary of the Tay some 30 miles north of the area, show that the prevailing winds are between Forces 1 and 6 and are of a southerly or westerly direction. The strongest winds of Forces 7 to 12 come from the north and east in the first five months of the year or from the south or west from September to November. The situation of the Lammermuirs, at the eastern corner of Lowland Scotland, combined with the north-easterly gales and low temperatures of winter and spring, explain the frequent severe snowstorms of the area.

The climate is comparable with that found in hill and mountain regions of Britain with warmer summers and a lower rainfall than many others (Table 2).

History and Land-Use

From the time the ice retreated at the end of the Glaciation till between 2000 and 4000 B.C. the land forming the Lammermuir hills must have borne a succession of vegetation types starting with barren tundra and rising to some form of woodland or scrub. While there were deer, the Great Ox or urus, wild swine, beavers and many smaller herbivorous animals, there were also many carnivores to prey upon them so that they would not have existed in such densities as to have caused a deep impression on the vegetation. With the coming of man the vegetation did alter, but at what rate it is difficult to ascertain. It can be said that most of the low ground which now forms the arable land of East Lothian was under swampy forest or scrub and that settlement first took place on the coasts and along the slopes and valley sides of the hill region. A study of a similar place in the Cheviot Hills finds the Bronze Age sites high on the valley sides while those of the Iron Age occur 200 feet lower down. Farmsteads of Early Christian times appear 200 feet lower still and those of more recent times have moved another 200 feet to the valley floor itself.

The earliest evidence of man's presence in the Lammermuirs rests in some rather insignificant cairns and stone settings found on hill tops and high crests. These are burial sites which could be seen from the homesteads of the people and suggest that clearings occurred on these places but whether they were natural is not known. No trace remains of the original settlements nor any cultivated land. Relics of contemporary age found along the coast suggest that the people lived by hunting and fishing to a great extent and were but partially dependent on agriculture.

Of the next invasion of people much more is known. They came from the coasts of France and Belgium, arriving in the Lammermuirs about 100 B.C. On strategic positions near better land they built small townships within roughly circular or oval concentric walls and ditches. The White Castle (Ref. 61/68) and Friars Nose Fort (Ref. 66/63) are good examples of this type and another has recently been located north of the farm of Crichness in the Bothwell valley. The huts within its ramparts were circular on stone foundations in which were embedded vast numbers of upright tree stems about six to eight feet high supporting lighter poles arranged to form a conical roof. The wood used was mainly alder with some birch or willow and the alder stumps were much larger than is now normally associated with that tree. Alder stumps of a similar size can often be obtained at the base of the layer of organic matter in gley soils at the present day. This does not prove that no other trees were present as the people would naturally have chosen those trees with straight trunks which were soft enough to yield to their primitive tools. When the Romans arrived in the nearby areas they often built with oak, but they had better tools.

These people grew corn and kept large numbers of sheep, a few of the small Celtic oxen and the half-wild ponies of the time. They may also have possessed fowls, and pigs domesticated from the native wild swine. At this time the land was covered with forest or scrub, and the settlements are located in the upland slope or the coasts. The need for fields and the demand for timber for fuel, weapons and buildings, coupled with the grazing animals, which were allowed free range during the daytime, helped to extend the cleared land about the settlements. The defensive positions were chosen as much to protect the inhabitants and their flocks from wolves, brown bears and herds of swine as from neighbouring tribes.

The sites in the hill region are all associated with the routes of migration from the south, of which the Whiteadder valley is one, and the associated valleys. There are thus more Iron Age remains in the Whiteadder and Bothwell valleys than in the Monynut valley. Although there are many cairns, hut circles and wide circular ramparts in the district, only those which have produced archeological evidence can be considered, as stells and lambing huts of turf or stone were built up till the time that corrugated iron sheeting was manufactured, while cairns have been erected as direction posts for roads and landmarks throughout the whole period of written history.

The Romans left no evidence that they had ever lived in the area although they remained as near as Edinburgh for about 250 years and their chief road skirts the county boundary. The native people, called the Votadini, had migrated so closely ahead of the Romans that they probably knew about them and may have seen them in their former homeland. Although they were never a subject race they probably had a treaty with the Romans whom they supplied with corn, wool and meat. The peace and stability brought by the Roman army ensured that cultivation flourished and flocks of sheep were reared to feed the large and growing population. The clearings around homesteads must have expanded greatly at this time.

When the Roman army withdrew from Britain hordes of barbarian tribes from North Germany swarmed into the East Coast and a long period of unrest ensued. This was followed by a time of tribal warfare when small kings tried to extend their influence across the country till finally the two kingdoms of Scotland and England emerged. Naturally there was for a time much dispute over the boundaries of the two countries but in 1018 at the battle of Carham the Lothians and the Merse were taken finally by Scotland. Up till now agriculture had been carried on fitfully in the hills by tribes of rough, impatient people who were beyond the reach of the central authority.

From the tenth century to the thirteenth, when the Wars of Independence began, Scotland enjoyed a period of peace and great prosperity. Agriculture advanced and the people became relatively wealthy.

Great changes took place in these three hundred years. The Normans, invited north by King David, displaced the Saxon overlords and introduced the feudal system. They built stone castles, and some stone towers and farmsteads, such as Gamelsheil and Johnscleuch, date from this time though they probably rest on the sites of former wooden or turf buildings. The ending "-sheil" in many of the names suggests that these were places to which the people took their animals in summer for the pasturage.

Not until a much later date is there definite evidence of the presence of permanent farmsteads. The spread of Christianity in the eighth century had brought in the monks who were specialists in farming. Several of the Lammermuir farms were given to the Church, among them Maysheil, which went to the Priory on the Isle of May and Pensheil and Zadlee which went to Lindisfarne Abbey and later to Melrose. The farms were well stocked, as 300 breeding ewes, 30 bearing cows and 24 brood mares went with Maysheil.

At this time there was an active agriculture in the area dependent on barley and oat crops and sheep, with oxen used as heavy draught animals and ponies for lighter transport. Although the descriptions and documents are confusing and contradictory it seems that by 1420 the Lothians were scantily wooded and by 1500 almost bare of trees. There are many Acts of

Parliament of this time to preserve wood and promote tree planting and one in 1503 specifically forbids muirburning after March in any year.

The period of the Wars of Independence from the thirteenth century on saw no great advance in agriculture in the Lothians for they were the main battleground of the two contesting kingdoms. The countryside was frequently laid waste by English armies and such woods as were left were burned to prevent their giving cover to marauders and the wild beasts which still roamed at large. At the Union of the Crowns in 1603 little advance occurred, for most of the money left the country for the south with the court. The Union of the Parliaments in 1707 ushered in a period of prosperity, and cultivation spread across the plain of East Lothian. Fields were enclosed and most of the common land which existed on the hill part of each parish was divided up amongst local landowners and let out to tenants.

The picture presented by the Statistical Account of 1791 shows the Lammermuirs as bare of trees, consisting of heath and moor with strips of cultivated land on the more favoured places and a population of some 6,000 hill sheep in every parish during summer. Maps of the time show that the area was well provided with roads or tracks, the most notable being the Herring Road which runs from Dunbar to Duns over the hill from Woodhall (Ref. 68/72) joining the Garvald - Duns road at Johnscleuch. Most of the tracks follow the crest of a ridge. One runs from Stoneypath by Spartleton and Bothwell Hill to St. Agnes, another from the Chapel at Deuchrie by way of Zadlee to Caldercleuch and St. Agnes and another along the top of the crest of the Monynut Ridge. Many of these were used for droving beasts or carting peats or turves which were used for fuel by the local people from at least 1500 till recent times.

For the last 250 years the vegetation and the agriculture have remained fairly stable with the latter experiencing the boom years of the Napoleonic wars, the Crimean war, the first and second world wars and interwar depressions of varying severity. The great period of prosperity up till 1810 saw many small independent farms in the hills. Much of the steeper but smooth contoured slopes bearing gorse and juniper which was broken in for cultivation then had a value beyond all reason. The effect of the succeeding depressions has been to wipe out the small farms and concentrate the land in the hands of lowland farmers holding large tracts of the adjacent upland fields. The small farmhouses were used for a time as dwellings for shepherds who often cultivated gardens and vegetable patches but these too have become ruins as the herds have been moved to new houses on the margins of the hills. The cattle which appeared in increasing numbers during the Napoleonic wars also decreased afterwards.

During the 1939-45 war much cultivated land was ploughed up and cropped with oats or potatoes and turnips and has since been laid out as permanent pasture for use as complementary grazing with the heath and moorland.

The hill ground is used for breeding and rearing flocks of sheep. These are entirely of the Blackface breed at present, but in past times they have alternated in popularity with the Cheviots. Some pure bred flocks are kept for breeding but most are used for crossing with Border Leicester rams to produce Grey face lambs in the former case and Half breds in the latter. These are sold off the farm or taken to lower pastures for further crossing. The Lammermuir hill pastures are noted for their high productivity, the stocking rate being the highest for any hill area in Scotland reaching one breeding ewe per one and a half acres in some places.

Very few cattle are kept on the hill. The farms usually keep herds of beef cattle for feeding and rearing and of recent years there has been a 40% - 60% increase in the number of milch cattle. The stable income from a monthly milk cheque is of great value to hill farmers. A tractor is now possessed by most farms, even the few remaining small ones but ponies are also kept for use in the winter time and the absence of very steep gradients makes it possible for some herds to do their rounds mounted.

The arable land adjoining the hill is cropped on the following rotation:

1. Oats	4. } Grassland
2. Turnips or potatoes or rape	5. } Grassland
3. $\frac{2}{3}$ Oats; $\frac{1}{3}$ Barley	6. } Grassland

The crops are normally consumed on the farm. Grass is used especially in its later years for making hay or for spring feed for ewes and lambs. There is no doubt that a proportion of the fertility of the arable land finds its way to the hill via the sheep.

Where the land is used by a tenant there is usually an agreement whereby the landlord has sporting rights on the moors. In the interest of both sheep farming and grouse shooting the moors are burnt regularly. Strips of heather or <u>molinia</u> moor are burnt over to stimulate young growth which is more nutritious than the old, woody or tussocky plants. The strip is left to grow for about fifteen years before its turn comes round again. This is regularly carried out in the Lammermuirs where the management is fairly intensive.

Rabbits were kept in warrens in Scotland from about 1000 or 1200 A.D. They may well have been prevented from spreading by the large number of predators which would have found these semi-domesticated animals easy game. The people of many districts had never seen a rabbit until the nineteenth century, when the ruthless extermination of carnivorous animals and birds, that accompanied the preservation of game for sport, allowed them to spread. They were also greatly encouraged by farmers, trappers and others who saw in them a good source of cheap food, or pocket money or even a living wage. Myxomatosis reached the area in autumn 1955 and not a rabbit was seen after the spring of 1956. While the changes in vegetation fall outside the scope of this work as the survey was completed in 1956, there is no doubt that the Agrostis-fescue pastures have especially benefitted from the change and many a shepherd had cause to bless the disease in the drought of late 1955, which might otherwise have created a shortage of food for the ewes.

Some of the land is used as a gathering ground for the reservoirs of Thorter and Whiteadder which supply the burghs of East Linton, Dunbar and North Berwick.

For the last two thousand years this area of the Lammermuir Hills has been under the influence of grazing animals, mainly sheep, and the management regimes of a settled agriculture, which have transformed the vegetation from scrub or woodland to heath and moorland. The change occurred slowly but was completed probably by 1500 and certainly by 1670. For about 250 years the vegetation has been in balance with the fauna and the human population, fluctuating with events in the world at large and no doubt undergoing slow changes inherent in the system, but nevertheless maintaining a stability greater than that of most farming systems.

In this section an attempt has been made to present a coherent picture of the land as it was and is rather than an evaluation of evidence from documents. For this the author is indebted to several farmers and shepherds from whom he obtained information in the course of conversation. He has also built up this picture by talking with Professor Stuart Piggot of the Department of Archaeology, University of Edinburgh, and Mr R. Feacham of the Royal Commission on Ancient Monuments, Ministry of Works, Edinburgh. Among the books consulted but not listed in the bibliography at the end are the following:

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SECTION 1

THE MAP SURVEY OF THE SOILS AND THE VEGETATION

Chapter III

METHODS

The work was begun by a rapid survey on foot with visits paid to several places in the area to ascertain the main soil types and plant communities present. The soil survey was made first and the vegetation map next, but the work of the two overlapped to some extent. The method of mapping soils was that used by the Soil Survey of Scotland, as described by Glentworth (1954). As the whole region was covered on foot, small pits about 18 inches deep by 15 inches wide were examined at intervals where it was thought necessary and their features recorded on the map. When enough information had been gathered from a place, boundaries were drawn in based partly on the map data and partly on the form of the landscape. No surveying instruments were carried, but a compass, an abney level and a pocket aneroid were occasionally used to check positions. Latterly the compass was found sufficient. The boundaries were sketched using contours, fences, streams and stells or other objects as guides for fixing position. At the same time notes were made on the vegetation.

The vegetation survey was based on methods outlined by Fraser (1940). The ground was covered again and a statistical survey (Section 2) was made at the same time. Boundaries between vegetation types were drawn in the field and later corrected in the office after comparison with aerial photographs.

During the operation, from first survey to final map, use was made of the new Ordnance Survey $2\frac{1}{2}$ inch to 1 mile maps. This scale of 1:25,000 imposes certain limitations on the surveyor. A line 0·25 millimetres wide on the map, such as is used to delineate boundaries, represents 6·25 metres or 20 feet on level ground and more on a slope. In practice it is impossible to draw in an area of less than $2\frac{1}{2}$ acres (3 mm. x 5 mm. on the map). Small areas of distinct types occurring amongst another type could thus be ignored unless they covered more than 25-30% of the area, when a "complex" was recorded. Such areas are few. It was found that where two types merged into one another the cline could only be shown on the map if it occurred over a distance of more than 300 ft. (5 mm. on the map). As this rarely occurs in the Lammermuirs each area is defined by boundary lines. In a few places where types succeeded each other rapidly over a steep slope it was only possible to map those occurring as large areas and the smaller types had to be missed out.

At all times the vegetation or soil occurring at a site was assigned to a particular type and every effort was made to avoid splitting the classification further by the use of intermediate or "wastebasket" divisions. Areas mapped as complexes are places where two, or occasionally three, distinct types occur in a mosaic of patches too small to map. They are marked by the symbols and successive stripes of colour of the types which make them up.

Map 1 is a basemap made from four sheets of the Ordnance Survey 1:25,000 series, Nos. 36/37, 36/66, 36/77 and 36/76. It shows all the topographical features of the area. Map 2 is a soil map and Map 3 shows the vegetation. These latter have been drawn on sheets of Ethylon, a transparent plastic, so that they may be laid on the base map singly for comparison with the topography or together to show more effectively the relations between the soil types and the vegetation. The boundaries were drawn with a size 1 Rapidograph pen and the different units are given a symbol and a colour, the latter being laid on with crayon.

Chapter IV

THE SOILS

Land surface, when exposed to the atmosphere, undergoes a process of physical and chemical decomposition or weathering, whereby the mass of rock is transformed into an accumulation of particulate material with the surface containing a high proportion of fine particles and the composition becoming coarser towards the base which may consist of large rock fragments only. This material is easily eroded away but if it remains in situ for a time it will obtain a cover of vegetation which gives it some stability. The dead material from the plants accumulates slowly and decomposes to form a dark finely divided substance called humus, which may remain at the surface or become mingled with mineral matter. Water percolating down through the soil dissolves salts from the mineral particles and various substances from the humus which may be carried away in the drainage water or deposited at lower levels.

The soil is thus a stratified mass of rock fragments mixed with organic matter. The form taken by a sequence of strata, called separately horizons, depends on the conditions under which the soil was developed. Horizons can be described in terms of their physical characters as they appear in the field or according to their chemical characters as samples analysed in the laboratory.

The vertical face of a pit dug in the ground, showing a sequence of horizons, is called a soil profile. The profile, which is the product and the reflection of all the factors which have formed the soil, can be used as the basic unit for comparing and classifying soil types. The horizons fall into four groups, the layers of organic matter, the mineral layers subject to leaching, the A horizons, the mineral layers in which some materials are deposited, the B horizons, and the parent material or C horizon. A soil profile typical for this country is shown in Diagram I (p76). The various horizons are as follows:

L Undecomposed plant debris.

F Partly decomposed plant debris.

H Finely divided, wholly decomposed organic matter showing no recognisable material to the naked eye.

A_1 Mixed mineral and organic matter.

A_2 Grey mineral layer, often light in texture and always low in organic matter, subject to strong leaching.

B_1 Thin layer in which sesquioxides have been deposited to form a concretion in the form of an iron pan.

B_2 Mineral layer with bright colouring showing marked effect of staining by iron oxides.

B_3 Mineral layer, often lighter in colour than the succeeding horizons, and usually hard and compacted or indurated.

C The parent material of the soil.

Where the water table is high, oxygen is cut off and the subsequent reduction of mineral salts gives the soil a blue, green, or olive or grey colour. This effect, known as gleying, is denoted by the letter "g" after the horizon symbol.

The factors which influence the development of a soil have been described and discussed in several books (Jacks 1934, Jenny 1941, Joffe 1949, Robinson 1949) and many papers. They are described here only to illustrate features of the soils of the area studied and the system of classification employed.

The parent rock determines, by its resistance to weathering, the amount of material available for soil formation, and by its mineral composition, the texture and base status of the resulting soil. Texture strongly influences the waterholding capacity, and the rate at which surplus water can drain away. The more clay in the material, the more likely is the drainage to be impeded. The base status and the drainage influence the species content of the vegetation and the rate of decomposition of the litter derived from it.

In the area surveyed there are three lithological rock types from which the parent materials of the soil may be derived. They are the Silurian gritstones and shales of the Llandovery series, and the Wenlock series, and a conglomerate of Old Red Sandstone age.

The first two are so alike that the Soil Survey of Scotland does not distinguish between the parent materials derived from each (Muir 1956), and the last is composed entirely of coarse rock fragments with very little cementing material, derived from the Silurian rocks about it.

The action of ice during the glaciation left a layer of abraded material over the whole area. On the slopes and rounded hill tops this is a yellow brown to red brown fine sandy loam or loamy fine sand containing many stones. In the low lying central area and all shallow hollows the till is a stiff red brown clay loam to clay with low to moderate stone content. Soils are therefore developed on three parent materials, each derived from the same rock type. They are, one, a residual mantle from the direct weathering of bare rock on hill tops and steep slopes, two, a light textured till on gentle to steep slopes and some rounded hill tops, and three, a heavy textured till in hollows and near-level places. In valley bottoms the soils are formed on transported and resorted materials. The difficulty of representing these adequately on a small scale map excluded them from consideration.

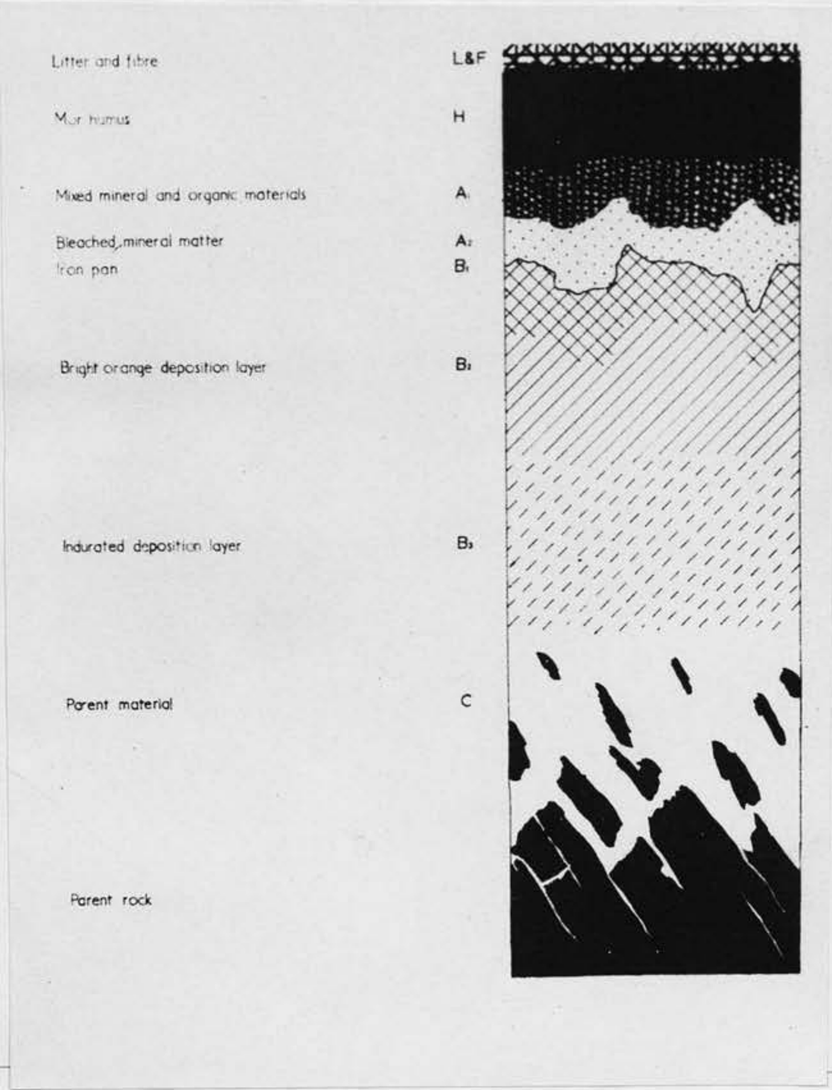
The site occupied by a soil and the surrounding topography have a strong influence on its formation. On a slope such as that illustrated in Diagram II, p76 the profiles at different points show entirely different characters. As the conditions change over the slope, so the soils change. Generally, fine material creeps down the slope and accumulates at the base. The upper soils are therefore shallower, younger and lighter in texture than the lower. The water table is furthest from the surface at the top and approaches it steadily towards the base where it may be above soil level. A soil at any point receives both the water from the sky above and that from the soil above. There is a tendency for the upper soils to be relatively poor in bases, and the lower series to be richer because the latter are composed of more weathered material and receive percolating water which has leached the former.

There are five recognisable profile types which are illustrated in Diagram III and are described briefly below.

No. I is a shallow soil with excessive drainage, a thin layer of organic matter and a bright orange B horizon.

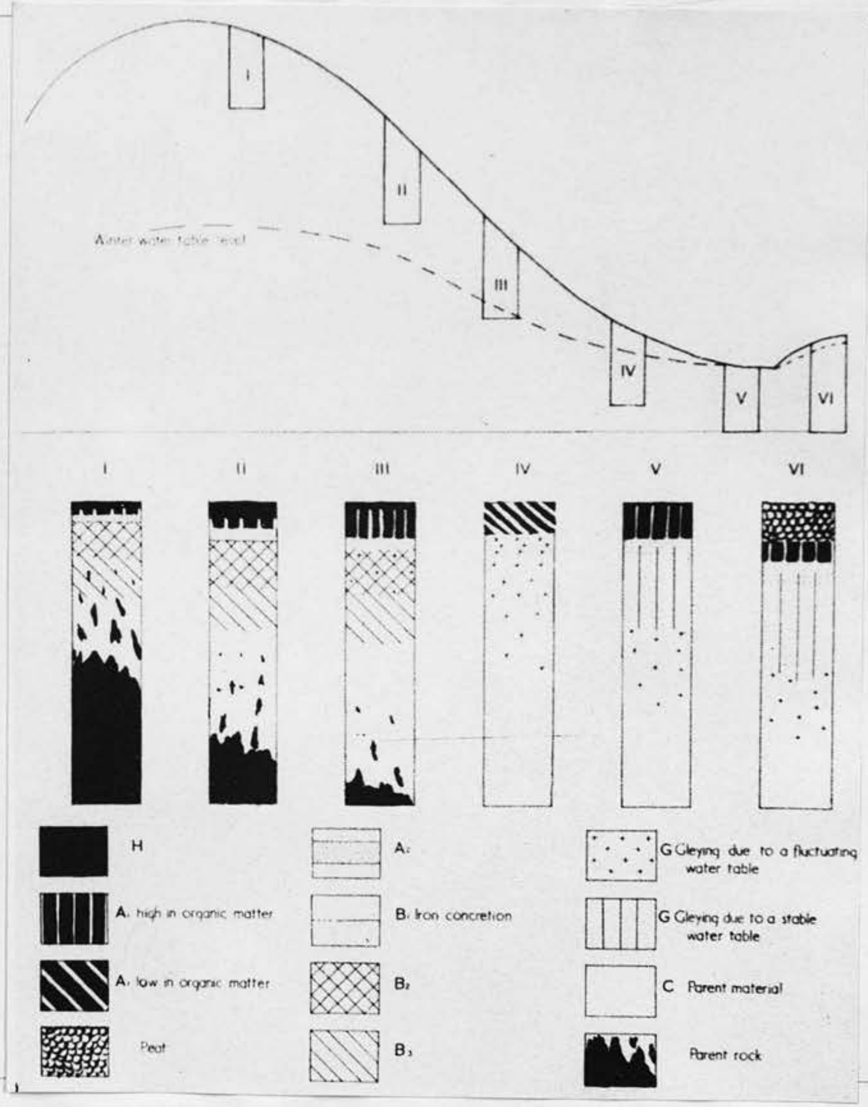
No. II is freely drained, has a deeper layer of organic matter, a bright orange B horizon. It is the normal soil of older classifications.

No. III often has a still deeper layer of organic matter or A horizon. It is recognised by the presence of slight rusty mottles in the B



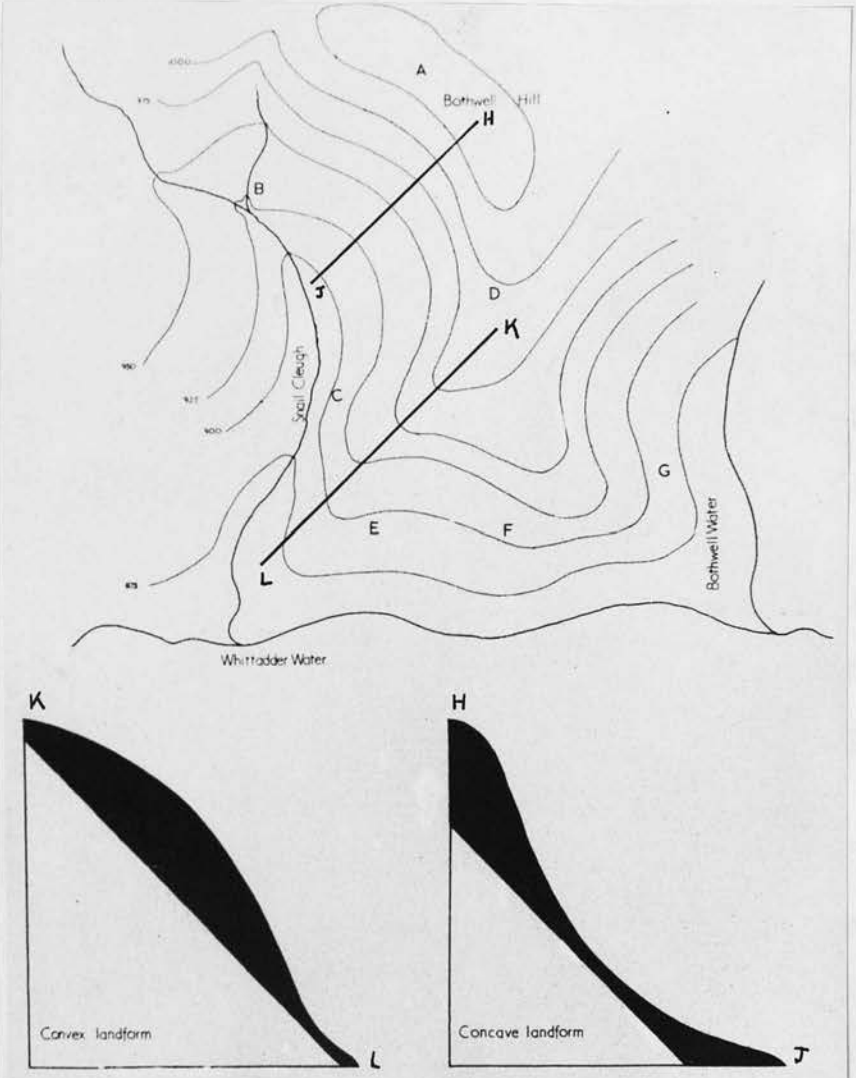
Diag I

Podzol profile showing horizon notation used. (p.72).



Diag II

The range of soil types on a normal slope. (p.75)



Diag. III

Similar gradients may have different forms which influences the condition of the drainage. KL is a convex slope and HJ a concave slope. (see p 79).

horizon. It is imperfectly drained.

No. IV has poor drainage. The A horizon is of good depth but is low in organic matter and the B horizon shows mottling and gleying as a grey green colouring. Its characters are conferred by a high but fluctuating water table.

No. V has very poor drainage. The A horizon is often deep and rather silty in texture. The B horizons are blue grey to green grey in colour. The water table is often at the soil surface.

Such a sequence of soils, when repeated over a countryside is a catena. They have been described in Canada (Ellis 1928), East Africa (Milne 1935), West Africa (Morrison *et al* 1949) and North-east Scotland (Glentworth 1940). They have been used as a basis for soil classification by several workers (Butler 1948, Ellis 1928, Milne 1947, Thomas *et al* 1943, and Glentworth and Dion 1950).

Climate acts mainly through temperature and rainfall. In the Lammermuirs the temperatures are typical of those of hill areas and the rainfall is low. The soils are therefore mostly podzols and associated gleys or brown forest soils and associated gleys.

Vegetation is not an independent variable (Jenny 1941). The soil type determines the initial vegetation, but once established the plants can, by their rooting habits and the type of organic matter produced, influence the soil. When the plant cover is composed of Sphagnum or shrubby heath plants, an acid organic matter with a slow decomposition rate is produced. This layer tends to increase the acidity of the mineral part of the soil and aids the leaching process so that podzolisation occurs. A grassy vegetation produces a milder, easily decomposed humus which mixes intimately with the mineral soil and aids in the formation of a brown forest soil.

The various factors do not act separately. They together produce their effect upon the soil (Jacks 1932).

The various features of each horizon are now described in a standard form. They are treated in order: colour, followed by texture, structure, consistence, organic matter, mottling, stone content, roots and, lastly, change into the next horizon. All these features are described by adjectives with precise meanings which are defined in the Soil Survey Manual (U.S.D.A. 1951). A convenient summary is given by Muir (1956).

In the following account each type of soil is described separately. The type is designated by a letter of the alphabet which is followed by the name.

The distribution of the blocks of each type and the average size of the blocks noted, whether they are clustered or scattered, appear over the whole area or in a particular site. The terms indicating size are: small, up to ½ inch diameter on the map, medium, up to 2 inches, and large, over 2 inches.

In describing site characters, both the slope and the land-form are given. Slope is described in standard terms (U.S.D.A. Handbook 18, 1951), level, gentle, moderate, steep and very steep. Landform is important, for it can affect the drainage profoundly. Diagram III shows a typical hillside of varying land-form. The areas enclosed by DCE and DFG have convex slopes which bear a large proportion of dry soils while the areas ABCD and DEF enclose concave slopes bearing mostly moist or wet soils. (p 76a)

Altitudinal limits, aspect and degree of exposure are also given. This is followed by a description of the soil profile.

The plant communities are treated in a similar manner.

The greatest problem confronting the soil systematist is the fact that no single criterion can be used for separating the various groups, as is possible with plants and animals which possess constant features in their reproductive organs. The morphology of the unit, the profile, depends on the action of a number of interrelated factors. Each individual is almost independent, there being no equivalent of the interbreeding group which becomes a population through the stabilisation of genetical characters. This means that within any soil type all the characters can vary greatly and all the recognisable types grade into each other. In order to place an individual soil in a particular category, whether it be at the series level or at the level of a major soil group it must be judged on the basis of several characters. It need not fulfil all the requirements of the group to which it belongs as long as it possesses most of the common characters (Muckenhirn et al 1949).

At the present day the broad general grouping of soils has been settled. This is based on the character of freely drained soils in all regions of the world, and they occur in bands or zones corresponding with the climatic zones. Those under study in this work are either of the Podzolic group or of the Brown Earth group. This sort of classification leaves the gleys out as Intrazonal soils. At the level of the individual soil profile it is possible to arrange the various kinds in a clear order, and in this case a drainage catena is used. It is at the intermediate levels that the system of classification has not yet been decided upon. In view of the fact that a truly natural system cannot be produced (Robinson 1949) some form of filing system must be used to enable different workers to correlate their findings.

In a small area, the classification becomes simpler than in considering wide regions, as the number of units is small and the variation low. Once the soils had been identified it mattered little for the purposes of survey what they were called. The terms originally used were based on those used by Ogg (1935) in a study of some profiles from the Moorfoot Hills, on the writings of Robinson (1949) and Kubiena (1953) and on the terms defined in Soil Survey Notes No. 6 (1950) and No. 7 (1951). These were later modified to agree with the system used by Muir (1956) in his survey of soils in Roxburghshire.

Table 7. Classification of Soil Types

Division	Major Soil Group	Subgroup	Drainage Classes I	II	III	IV	V	VI
Gleys	Surface water gleys	(Noncalcareous (gleys				K	L	
		(Peaty gleys				M		
Leached soils	(Podzol (	Peaty podzol with iron pan		——P——		—J—		
	(Brown (earth	Brown forest soil of low base status		——C	D			
Organic soils	(Blanket (peat	Hill peat						O
	(Basin (peat	Low moor						O
Skeletal soil		(Screes	SZ					
		(Colluvial soil	T					

Table 7 shows the systematic position of each soil type according to this classification and its relationship with the other types. The subgroups are the most important categories in this study for they very nearly correspond with the individual units in the area. Where two or more types occur within a subgroup they are very closely related and separated only by a small difference in drainage characters. In this, as in all types of soil classification, it is possible to place individual profiles under two or more categories due to some variation in their characteristics. There are type M soils which possess a B_1 horizon and could easily appear as type J. There are type L soils with a layer of sedge peat between the A_1 layer and the B_g layers, which could go into type O. The aim was always to group the soils, as Robinson (1949) directs, as they resembled each other in a number of ways, even if every condition is not met, rather than on rigid criteria.

Division of Leached Soils

Drainage water moving down a profile dissolves minerals from the upper horizons. Some, such as the silicates and sesquioxides of metals, are deposited lower down and others are carried away entirely. Such soils have upper horizons devoid of free lime and with an acid reaction. The B horizon is of a fairly uniform colour.

Major Soil Group: Brown Earths

Soils with organic matter in the form of mull or moder. They are neutral to weakly acid in reaction. In the normal type the B horizon has been formed by deep seated weathering in the presence of abundance of air and water.

Sub-group: Brown Forest Soil (low base status)

These soils are formed under lower temperatures and higher rainfalls than the normal brown earth, and therefore tend to approach the podzol in morphology. The organic matter is a silicate moder, or very occasionally a mull and the reaction of the upper horizons is acid. The horizons merge into one another, and the B horizon gains some or all of its bright brown colour from the deposition of substances leached from above.

Soil Type C: Brown forest soil of low base status (i)

This type of soil is to be found in small to medium sized areas over the map but mainly along the northern escarpment. It is most frequently seen on steep convex valley sides but may also be found on hill tops where the rock is close to the surface. In altitude the patches range between 700 ft. and 1,150 ft. with a very few higher and only in one case reaching 1,275 ft.

The parent material is of the lighter type. In most cases shattered rock appears about two to two and a half feet below the soil surface but occasionally, and this is especially true of the northern escarpment on the Monynut Ridge, there may be a considerable depth of glacial till.

These soils are freely drained and in some cases excessively so.

Profile Description

Horizon Symbol	Depth	
L	½"	Litter
F	½"	Partially decomposed roots, leaves and stem bases
H	1" - 2"	Dark brown humus with bleached sand grains and roots plentiful
A	2" - 6"	Yellow brown fine sandy loam; weak medium crumb structure; friable; low in organic matter; roots abundant merging into
B_2	6" - 12"	Reddish yellow brown fine sandy clay loam, weak fine crumb; friable; roots frequent; stony clear change
B_3	12" - 15"	Reddish brown sandy clay loam; weak blocky structure; friable; few roots; very stony merging into
C	15" +	Red brown to olive brown sandy clay loam interstitial in shattered rock

Table 8. Analysis of the horizons of a brown forest soil (i)

	Loss on Ignition	pH
H	60% - 70%	4.3
A	15% - 47%	4.6
B_1	5% - 9%	4.8
B_2	4%	5.0

The upper horizons, L, F, H and A are about the same depth in all the soils of this type but the B horizons may be deeper or shallower. In some cases only a B_2 is present, the soil running straight into shattered rock at a depth of about 11". The figures given for loss on ignition drop sharply from the high level of the H horizon. The pH though low is for this area only moderately acid.

Soil Type D: Brown forest soil of low base status (ii)

Many small to medium sized, often finger shaped, patches are scattered across the map, occurring mainly along the northern edge and on the three ridges but absent from the central area. The type mainly covers moderate to steep valley slopes where the land form is slightly concave. It is found between 700 and 1,275 ft. running deep into the hill masses and is generally in situations which are sheltered or only moderately exposed to the climate.

The parent material is of the lighter class and is somewhat deeper than that which gives rise to type C.

The drainage class, as shown by the slight mottling on the lower horizons, is poorer than in type C but tends to fall between free and imperfect. It is sufficiently different to merit separation from soil type C and yet too well drained to be included amongst the gleys.

Profile description

L	0" - ½"	
F	½" - 1"	Partly decomposed roots, stem bases and leaves
H	1" - 2"	Dark brown moder organic matter. Full of roots. This and above layers forming a mat
A	2" - 11"	Buff to grey brown sandy loam, weak medium crumb structure, friable, low in organic matter, roots frequent, bracken rhizomes frequent in upper part, few stones, merging into
$B_{2(g)}$	11" - 16"	Yellow brown sandy clay loam, weak medium subangular blocky; firm; low in organic matter; frequent medium faint ochreous mottles; roots frequent, merging
B_3	16" - 20"	Red brown clay loam; weak medium blocky; friable; low in organic matter; few fine faint ochreous mottles; roots fewer; many stones, merging
C	20" +	Red brown clay loam in interstices of rock fragments or very stony, few roots, no mottling

Table 9. Analysis of the horizons of a brown forest soil(ii)

	Loss on Ignition	pH
H	47.4	4.56
A	17.24	4.76
B	6.01	5.10

The profile is deeper than the previous but closely related type, and shows a weak mottling in the B_2 horizon. Loss on ignition is lower in the upper horizons and the pH is slightly higher. The type occasionally shows greater mottling and this is usually associated with a more grey colour in the A layer, sometimes half rotten stones and in one case with a rather heavier texture than usual.

Major Soil Group: Podzol

The soils of this group develop an H layer of mor, several inches thick and with a strongly acid reaction. Leaching is so strong that the A horizon may be markedly bleached and the deposition of iron oxides leaves a bright rusty colour in the B horizon.

Sub-group: Peaty podzols

The oxide deposition mostly occurs at the top of the B horizon. Two types have been recognised, the first in which the B_1 horizon is discontinuous and soft, even diffused over an inch of profile and in which the H layer is from 3 to 7 inches thick and another with a B_1 consisting of a tough $\frac{1"}{16}$ thick iron pan impermeable to water with 6" to 12" of mor and a gleyed A_2 horizon. In either case the A_2 does not stand out as a definite grey layer but is stained very dark brown with humus material, its presence being recognised by the bleached sand grains and its high mineral content compared with the layer above.

Where the H horizon exceeds 12 inches in depth the soil is classified as peat.

Soil Type P: Podzol (i)

This occurs in medium to large sized areas which form a ring around the outer edge of the map - thinnest at the north-west and best developed on the southern portions of the three ridges. The typical site is a moderate to steep slope of convex form often readily drained by a swiftly falling stream. The altitudinal limits are 800 ft. and 1,500 ft.; it faces all aspects and tends to occupy more exposed places.

The soil is derived from the lighter of the two parent materials, and it varies from almost stone free in the B_2 horizon to very stony.

The soil material is always freely drained below the B_1 horizon and above it ranges from almost free to imperfect.

Profile Description

L	½"	Litter
F	½" - 1"	Fibrous material - roots, rhizones, *Calluna* stems, grass, stem bases, etc.
H	1" - 4"	Black decomposed mor. Greasy when wet, coherent, almost felty when moist and shrinks when dry into sharp angled aggregates; sharp to
A_1	4" - 5½"	Very dark brown loam; moderate fine sub-angular blocky to platy; friable; high in organic matter, occasional stones along the base; roots plentiful; merging into
A_2	5½" - 8"	Dark grey brown loamy sand; weakly very coarse platy; weakly indurated; low in organic matter; roots present often forming a mat at the base; stony sharp change to
B_1	8"	Some of the stones this level have a coating of ochreous slime, or a layer of mineral particles adhering by means of an ochreous cement
B_2	8" - 12"	Rusty orange hued grey brown sandy loam, moderate medium granular, slightly plastic firm; no organic matter; few fine faint pink mottles; few roots; stony; merging into
B_3	12" - 20"	Pinky grey brown sandy loam; moderate medium granular; very firm, hard; indurated; no organic matter; stony, no roots, merging into
C	20" +	Red brown sandy clay loam, very stony

The A_1 layer may be absent or mixed in with the A_2 layer and the two vary greatly in depth even on a single profile face. At the base of the A_2 the root mat often produces a mass of decaying organic matter similar to a "humus pan". The bright colour of the

B_2 layer is in marked contrast to the sombre colours of the layers above and the duller tones of the B_3.

The shallow horizons and the siting make this type liable to drought especially in late spring and early autumn.

Table 10. Analysis of the horizons of a podzol

	Loss on Ignition	pH
H	70 - 90%	3.8
A_{1-2}	10 - 20%	4.3
B - C	5 - 10%	4.8

Loss on ignition is very high in the H layer and drops sharply in succeeding layers. pH is low and rises in the lower layers. In the A_{1-2} layer the sand constituent is high and the clay low while in the B - C layers the former falls and the latter rises.

Soil Type J: Podzol (ii) with gleyed A_2 horizon

Type J occurs in large tracts over the map with the exception of the centre and the extreme edges. The sites it occupies vary from the gentle to moderate slopes on flattish, low ridges between more sluggish drainage channels to moderate to steep slopes with concave form. Some rounded hill tops also bear this soil. It is found between 600 ft. and 1,475 ft. but mostly between 1,000 ft. and 1,250 ft. There is no particular aspect and it tends to appear on more exposed places.

The parent material is of the lighter type, and occasionally intermediate between it and the heavy type.

A strongly developed iron pan makes drainage so poor above that the A_2 is always gleyed while the B horizons vary from free to imperfect.

Profile Description

L	0" - $\frac{1}{2}$"	Litter
F	$\frac{1}{2}$" - 2"	Fibrous mat of partly decomposed stem bases, rhizomes, Calluna stems, roots and leaves clear change to
H	2" - 9"	Very dark brown mor humus, greasy when wet and shrinking to sharp angled aggregates when dry; roots plentiful; clear change to
$A_{1+2(g)}$	9" - 12"	Dark brown gritty sandy clay loam, weak blocky to platy structure; friable; moderate organic matter; many coarse prominent grey mottles; roots frequent; stony, sharp change to
B_1	12"	Thin ($\frac{1}{8}$") iron pan, sharp change into
B_2	12" - 16"	Rusty orange red sandy loam; moderate medium granular; slightly plastic, firm; no organic matter, very few faint grey mottles; roots rare to none; stony; merging into
B_3	16" - 23"	Pinky grey brown sandy loam; moderate medium granular;

		very firm, hard; indurated no organic matter; no roots; stony; merging into
C	23" +	Red brown stony sandy clay loam

The deeper H horizon, the gleyed A_2 and the invariable presence of an iron pan are the criteria which separate type J from type P. The whole soil profile is deeper and it is not common for the B_2 horizon to run straight into the weathering rock. The root mat with its "humus pan" is common here too and helps to obscure the difference between layers A_1 and A_2. As in type P the B_2 horizon is bright coloured, though occasionally slightly mottled, and soft, and the B_3 is paler in colour and often indurated.

Table 11. Analysis of the horizons of a podzol with gleyed A_2.

	% Loss on Ignition	pH
H	60.5 - 91.2	3.5 - 4.7
$A_{1+2(g)}$	8.6 - 45.3	3.9 - 4.8
B_{2+3}	5.6 - 20.4	4.5 - 5.2

The low pH values rising in the lower layers are a feature of this soil type, slightly higher than type P probably on account of the higher water content which would have a reducing effect. Loss on ignition is very high in the H horizon and decreases sharply below. The Mechanical analysis is the same for both horizons.

(b) Sub-group: Organic soils

These are soils with a mor humus layer of over 12 inches in depth. The depth of 12 inches was chosen arbitrarily by the Soil Survey of Great Britain (1950) because it works in practice for separating soils for mapping purposes. There was no reason to deviate from this practice in the area under survey as that level sees a change from one type of humus, Calluna mor, to another, Calluna - Eriophorum - Sphagnum mor.

There are two ways in which peat forms. Hill peat is derived from peaty podzolised soils with iron pan on very flat, usually high lying, areas with poor drainage. Once organic matter has accumulated to a depth of about 12" Sphagnum and Eriophorum vaginatum colonise, invade the area and share it with Calluna. The resulting peat is built of the remains of all three species. Basin peat arises in hollows or ponds which have been silted up. The remains of vegetation lying above the normal water table are subject to strong leaching and acidification. The area is invaded by Calluna, Eriophorum and Sphagnum which build up a layer of mor humus. Under the conditions of grazing, peat cutting, and burning the vegetation of both areas becomes identical and the subsequent soils formed by them identical.

In a study of this nature which deals with the relationships of soils and vegetation the observer must take the facts as he finds them. Although the siting and the life histories of these two peat types are apparently different the end product is the same and the investigator must classify them together.

Soil Type O: Peat

Areas of peat soil occur as medium sized patches forming a discontinuous ring around the map. They are found on rounded hill tops and flattish shoulders at 1,100 ft. to 1,500 ft. On the western side of the lower limit is 1,100 ft. and on the eastern 1,225 ft. A few small depressions at 1,050 ft. also contain peat.

Profile description

The L and F layers may be 3 or 4 inches thick and contain much more mors than in types P or J.

The H layer is from 15 inches to beyond 6 feet thick. It is an unstratified mass of black mor humus in which, with the aid of a hand lens, the remains of Calluna, Sphagnum and Eriophorum vaginatum can often be made out. Roots are plentiful in the L and F layers and frequent in fissures in the H layer.

A profile from Heart Law (Ref. 71/66) showed below an H layer of 19" the profile of a typical peaty podzol with iron pan. At Dogbush Knowe (Ref. 68/67) a peat layer of 22" covered a series of horizons typical of a peaty gley soil. Where it was possible to see the underlying mineral soil the majority were of the first type and the second occurred only in a few areas near the central region. In basin sites the H layer was always too deep for the mineral soil to be examined but the edges usually had a non-calcareous gley soil occupied by a rush community.

Most of the roots are to be found in the L and F layers and in the upper foot of the H layer.

The organic matter content ranges from 89% to 95% and pH from 3.1 to 3.9.

Division of Gleys

These soils have been developed below a permanent or a fluctuating water table. The mineral horizons are blue, green or grey and may show many ochreous mottles, colours derived from the reduction of iron salts, which mask the original colour of the parent material. The topsoil may be mineral or a peat less than 12 inches deep.

Major Soil Group: Surface water gleys

The drainage water percolates through the upper layers of soil material only, rarely penetrating the parent material so that the effect of gleying decreases with depth. The $B_{3(g)}$ and C horizons may not show any colouring other than that which is natural to them in the freely drained state.

Sub-group: Non-calcareous gleys

A thin, up to 1 inch, H layer, and a mineral top-soil devoid of free calcium are characteristic.

Soil Type K: Non-calcareous gley with poor drainage

Small areas are distributed over the whole map and large areas occur in the centre and on the north part of the middle ridge. They appear in the lower parts of tributary valleys and on gentle to moderate slopes of concave form between 800 and 1,200 ft. Aspect does not seem to be important in determining their occurrence and the sites are by their very nature in sheltered positions.

The soil is always derived from the heavy parent material but the sites along the northern edge and in the southern parts of the ridges tends to be lighter in texture than that of the central area.

Drainage is poor.

Profile Description

L	¼"	Litter
F	½"	Partly decomposed litter of roots, stem bases and leaves.
H	½" - 1"	Dark brown organic matter; sharp change into

A_{1g} 1" - 4" Medium grey brown sandy clay loam, moderate medium blocky; firm; moderate organic matter; few fine distinct mottles associated with abundant roots; stones few; merging into

A_{2g} 4" - 8" Light grey brown sandy loam, weak fine blocky, friable; low organic matter; frequent fine distinct mottles; roots frequent; stones frequent; merging into

B_{2g} 8" - 16" Grey yellow sandy clay loam; moderate medium prismatic; low organic matter; frequent medium distinct ochreous mottles, stones frequent, coated with grey clay; roots frequent

B_{3g} 16" - 20" Yellow grey sandy clay loam - red brown in centre of peds; moderate medium prismatic; few fine distinct ochreous mottles; stones frequent, coated with grey clay, roots few, merging into

B_{3g} 20" - 29" Reddish brown sandy clay loam, weak coarse blocky to medium prismatic; firm; peds coated grey, few moderate mottles associated with roots; stones frequent; merging into

C 29" + Reddish brown sandy clay, weak coarse blocky; very firm; peds with thin grey coat; roots rare; stones few

Table 12. Analysis of the horizons of soil type K.

	Loss on Ignition	pH
A	11.83	5.23
B_2G	7.59	5.46
B_3G	4.53	6.0

This soil is typical of those in which the water table is at the surface for most of the winter months and retreats 6 to 12 inches in summer. The upper layers are low in organic matter for this area and the clay content of the mineral material moderate. The pH is nearer neutral than most other soils.

Soil Type L: Non-calcareous gley with very poor drainage

Small to medium sized patches are scattered across the map. Most occur in the central area but they are frequent all over. Valley bottoms and level to gentle slopes of concave form adjacent to a drainage channel are invariably occupied by this type. It ranges from 700 ft. to 1,250 ft. and is mainly in sheltered positions although some of the higher lying types suffer a certain degree of exposure.

The parent material is always heavy. The drainage is very poor, the water table being at the soil surface throughout the year apart from conditions of exceptional drought.

Profile Description

L	½"	Litter
F	½" - 1½"	Partly decomposed organic matter with roots rhizome, stem bases, grass and rush leaves
H	1½" - 8"	Very dark brown silty loam, moder humus, very high in organic matter, sharp change to

A_1	8" - 13"	Very dark grey brown fine sandy silty loam; moderate fine blocky; friable; high organic matter; roots abundant; no stones; sharp change into
A_{2g}	13" - 19"	Grey brown sandy clay loam; weak medium blocky; plastic; low organic matter; uniform colour; roots frequent; no stones; merging into
B_{2g}	19" - 23"	Grey sandy clay; moderate medium prismatic firm; many medium distinct ochreous mottles, grey faces to peds and the few stones, roots occasional; merging into
B_{2g}	23" - 28"	Blue grey fine sandy clay; strong medium prismatic; very firm, plastic; few small rotten stones; grey faces to peds; roots few, with ochreous coating when dead, frequent; merging into
B_{3g}	28" - 36"	Grey sandy clay; weak coarse blocky structure; very firm, very plastic; interior of peds with red brown colour i.e. parent material colour and frequent medium ochreous mottling; roots few, dead ones with ochreous coating frequent; stones frequent; merging into
C	36" +	Red brown sandy clay; weak coarse blocky structure; faces of peds coated with grey clay; firm and plastic; few medium distinct mottles; stones frequent; roots rare

Table 13. Analysis of the horizons of soil type L

	% Loss on Ignition	pH
H	80	5.2
A_1	25	5.4
A_{2g}		5.67
B_{2g}	5	6.25

The H and A layers are the most variable in this type. The H horizon may be from 4 inches to two feet thick and in the valley bottoms it may show a layer of sedge peat and alder roots at the base. Sometimes a layer of typical A_1 horizon material will be between the H horizon and a layer of sedge peat and tree roots below. However deep the upper horizons the lower never fail to follow the above description except when close to a stream bed.

The relatively high pH, increasing with depth, is a feature of the type.

Sub-group: Peaty gleys

A well formed H layer of mor humus is present. The upper mineral horizons have no free calcium and an A_{2g} is always present.

Soil Type M: Peaty gley

The centre of the map is occupied by a large area of this soil type, broken only by the tributaries of the Bothwell water. Six smaller areas occur on the west bank of the Dunglass burn in the south-east. The sites are level to moderate slopes of convex form. The parent material is always heavy. The drainage is poor but water is not stagnant as the type always is well supplied with streams and small channels.

Profile Description

L	½"	Litter
F	1"	Mat of decomposing roots rhizomes, and leaves mixed with mor humus
H	1½" - 8"	Very dark brown humus, greasy and softer than <u>Calluna</u> mor. Clear change to
A_{1g}	8" - 11"	Dark grey brown fine sandy loam; moderate fine blocky; friable; moderate organic matter; few medium prominent ochreous mottles; roots frequent; merging into
A_{2g}	11" - 13"	Grey brown fine sandy loam; moderate fine blocky; friable; low organic matter; few stones, some having ochreous slime coat; roots frequent; sharp change to
B_{2g}	13" - 22"	Grey fine sandy clay loam; moderate fine prismatic, the interior of the peds are red brown with many medium and fine ochreous mottles; plastic, firm; roots frequent but many dead; stones often rotten, merging into
B_{3g}	22" - 28"	Red brown fine sandy clay; moderate coarse blocky to medium prismatic; faces of peds coated with grey clay; very plastic, very firm; few fine ochreous mottles; stones frequent; roots few; merging into
C	28" +	Red brown fine sandy clay; moderate coarse blocky structure; thin layer of grey to some faces of peds; very plastic, very firm; stones frequent; roots rare

The L and F layers vary from a trace to a depth of 3 inches, and the H layer may be from 3 to 11 inches thick. The A_{1g} may be missing or indistinguishable from the A_{2g}. Occasionally a thin layer of ochreous staining may be found at the base of the A_{2g} horizon. It may be in the form of an ochreous lime around stones or as a soft cement binding together groups of sand grains. The degree of gleying in B and C horizons varies from a slight coating of grey on the exterior of blocky peds in the B_2 only to an even grey with prismatic structure. As these are surface water soils the gleying decreases with depth and the parent material shows the normal red brown colour.

Table 14. Analysis of the horizons of soil type M.

	Loss on Ignition	pH
H	77.25	4.0
A_{1+2}	12.8	4.33
G	6.99	5.02

The loss on ignition is very high in the H layer but not as high as in Calluna mor, due perhaps to the high silica content of a grassy vegetation. The pH is generally higher than for other podzolic types but lower than for the noncalcareous gleys.

Division of Skeletal Soils

Immature or raw soils consisting of parent material which has undergone some weathering, usually physical, and in which soil forming processes have had no or very slight action. Where an A_1 horizon exists it is very thin. In some cases an H layer occurs, usually as a discontinuous cover or in patches.

Soil Type T: Colluvial soil

These soils are found mainly on the eastern part of the map. They occur usually where streams are actively eroding into boulder clay. The slopes are steep and very unstable. The most extreme type is completely bare of vegetation except for turves, or blocks of peat carrying heath plants slowly downhill. During summer the surface is dry and hard but rain turns it into a sticky layer which flows slowly downhill. During the winter season the bottom is continually receiving small stones, boulders and fragments of the till. The most stable forms have a cover of short Agrostis-fescue grassland above a thin (1") A_1 layer of low or moderate organic matter content but no further soil formation can be made out from the profile. This type merges into soil types C and D and may be kept in its present form by the heavy pressure of the rabbit population which by its tunnelling and grazing prevents the establishment of a stable vegetation type. It is worth noting that the White Cleugh (Ref. 71/65) had, by late 1956, a greater cover of vegetation than in 1955 when myxomatosis appeared.

Soil Type S: Scree Soil (i)

In all parts of the area there occur steep slopes on which the underlying rock outcrops near the top. Normal weathering sends masses of rock down the hill as rock slides or screes. Where the bedrock is shaley, the resultant material consists of flattish, sharp-edged rhomboidal fragments from two to ten inches in size, which slide easily over each other. Very few of the screes are so steep or unstable as to be completely devoid of vegetation. Most have achieved an angle near stability or below it and have a good deal of interstitial fine sandy loam material which provides a hold for the roots of plants. In areas bearing Agrostis-fescue grassland or Bracken fern a thin A_1 horizon of mull humus develops and where Calluna is dominant the beginnings of an H layer appear. In one place where a type O soil occupies the land above a steep slope, peat frequently comes down on to the scree giving a very mixed soil type.

Soil Type Z: Scree Soil (ii)

On some steep slopes the outcropping rock contains many bands of massive gritstone which weather to boulders between six inches and three feet in diameter. Screes of this type are all at such slopes as to be fairly stable and have developed considerable vegetaive cover. The interstitial material is composed of shaly stones and fine sandy loam in deep pockets between boulders. In some places a layer with mull humus up to four inches thick occurs and in others an H layer of <u>Calluna</u> mor of three inches was recorded.

Mixed bottomland

A narrow strip of flood plain and short steep eroded slopes border every sike and burn on either side. These contain a mixture of soil types in patches too small to be shown upon the map. This unit is therefore solely for convenience in mapping. It includes as parent materials, shingles, gravels, loams, silts, and silty clays in all stages of the soil forming process. The most prevalent types are a loamy sand with a one or two inch deep A_1 layer of mull humus or a silty clay loam topped by a layer of rush litter and an A_1 horizon of black silty moder, never very deep. The winter floods spread new layers of material over the old, or tear away great tracts which had earlier been built up and so the soils are usually in an immature state.

Cultivated land

Soils on land under cultivation or which had been cultivated at some time in the recent past have not been examined and the areas they occupy left blank upon the map. In two areas, The Sting (Ref. 69/67) and The Duddy (Ref. 70/65), there are series of "soo-back" ridges faintly discernible in late afternoon or evening light. As the soils on these sites appeared natural they were classified with the rest.

Chapter V

THE PLANT COMMUNITIES

The area bears a vegetation which may be described broadly in the terms coined by Pearsall (1950) as submontane. There are remnants of deciduous woodland all over, mainly in gullies and other places safe from animals or fire. The base slopes are clothed by a bent-fescue or <u>Nardus</u> grassland or by bracken. The upper places, often less steep, have a moorland or bog cover. The dominant environmental factors are firstly climate, secondly grazing and burning, and thirdly the soils. Within the limits imposed by the first two the soils determine the different communities. Apart from the remaining woodlands, the flora is composed of plants which are low growing, resistant to defoliation and capable of regeneration either by rootstock or seedling after fire. The flora is poor in species and many occur in most of the communities, which are often differentiated on the varying proportions of the same plants.

The various communities which have been recognised are differentiated either by the dominant plants or by the growth form of the major species. Heather moor has been split into six types according to the subsidiary species present. These six are constant in composition and recur over the area. As Nardus is ubiquitous, Nardus grassland is more difficult to delimit than other communities. In practice, as nearly all the Nardus grassland was a mixed grassland with no true dominant, any sward, from which Molinia caerulea in quantity was absent, and which contained more than about 20% Nardus stricta, was classified as Nardus grassland. Molinia and Nardus showed co-dominance over so great an area that a distinct community, type MN, was recognised. True Molinia grassland in this area always contains a proportion of Calluna - Molinia which cannot be shown on the map.

The description of each type which follows gives site characters, a picture of the form of the community and species lists. The latter are either a single list made up from field notes or a series of lists from particular places to show the variation within the community.

Table 15. Classification of plant communities

Symbol on map		
C		Agrostis fescue grassland
	g	Ulex europaeus
	j	Juniperus communis
D		Bracken Pteridium aquilinum

P	Calluna vulgaris heath
V	Calluna - Vaccinium myrtillus
J	Calluna with Juncus squarrosus, Nardus and Trichophorum caespitosum
T	Calluna - Nardus
U	Calluna - Trichophorum caespitosum
O	Calluna - Eriophorum vaginatum
K	Juncus articulatus - Nardus grassland
L	Juncus effusus
M	Molinia caerulea grassland
N	Nardus stricta grassland
MN	Molinia - Nardus grassland
S	Scree vegetation (various)
W	Woodland
o	Alder - oak woods
b	Birch - rowan scrub
c	Plantations of coniferous trees
No symbol	Mixed bottomland

Type C (including j and g): Agrostis-fescue grassland Table 16 p112

Small to medium-sized patches appear in all parts of the area, particularly along the northern margin. Many spots are too small to show on the map as it frequently occurs isolated in other types of vegetation. The sites are mainly on steep to moderate slopes of all types of contour form and all aspects and degrees of exposure. Probably there was once a much greater area of this below the present head-dykes and the surviving remnants may owe their existence to their unsuitability for cultivation due to distance from the farmsteads, stoniness, or irregularity of the landform. The type ranges from 600 ft. to 1,200 ft. in altitude, being most frequent on the lower ground.

The community is a smooth to tufted green sward composed of a mixture of small grasses and herbs. There is often no true dominant plant. Dominance is usually shared by Festuca ovina (agg.), Agrostis tenuis and A. canina. The great number of species found is partly due to the variation in the community under different environmental conditions. Nearly every plant present on the hill appears in one or other of the lists. Table 17 p115 gives six lists of species which are constant for particular conditions. Those in the general list are constants in any Agrostis-fescue pasture and the others show up the relationships with other communities.

Table 16 gives species lists taken from different habitats to bring out the difference between facies of the community. Agrostis-fescue grassland falls naturally into place between the screes and the wet Nardus - Juncus articulatus flushes. The edges of the hill mass or crests of the ridges at the point where the land runs over steeply into the valley side often bears a type intermediate between this type and Calluna heath, often characterised by a high proportion of Nardus. Deschampsia flexuosa shows its preference for dry sites by its dominance on the driest of all.

Gorse, Whin and juniper appear on this type as isolated bushes on the drier sites. They are denoted by the letters "g" and "j" on the map. As no young seedlings of juniper can be found it may be dying out here as elsewhere (Fenton 1933, Elgee 1912). Gorse is often associated with rabbits, to whose grazing it is fairly resistant. Whin is seldom seen.

This is the most valuable grazing land on the hill and is preferred by sheep to all others. No doubt the concentration of animals has a strong influence in maintaining the species composition as this gets a greater amount of excreta than the other types.

Habitat

1	Excessively well drained almost scree
2, 3, 4	Freely drained soil
5, 6	Slightly poorly drained
7, 8, 9	Poorly drained soil
10, 11	Podzol with gleyed A_2 horizon

Table 16. Agrostis-fescue grassland, Type C

	HABITATS										
	1	2	3	4	5	6	7	8	9	10	11
Ranunculus repens							o	f	f		
Ranunculus acris							o				
R. flammula							o				
Cardamine pratensis								o	r		
Viola riviniana	o	o	o	f		o			f		
Helianthemum chamaecystus	o			o							
Oxalis acetosella						o			r		
Trifolium repens		r	f	f		f	c	f	c		
Lotus corniculatus	o	f	o	o							
Lathyrus montanus	o							f			
Potentilla erecta	f	f	o	c		f	f	f	c	o	o
Rumex acetosa		f				f					
R. acetosella	o	r									
Calluna vulgaris				c	f						
Vaccinium myrtillis	c		c							a	o
Empetrum nigrum		o	o	f							o
Erica cinerea	f		o							o	
Veronica officinalis			r		o				c		
Veronica chamaedrys		o					f				
V. serpyllifolia	f	f					f				
Euphrasia officinalis		r					f				
Thymus serpyllum	f	o	f	f							
Prunella vulgaris							o				
Plantago lanceolata		o	o	f			r				

Table 16 (contd.)

	HABITATS										
	1	2	3	4	5	6	7	8	9	10	11
Campanula rotundifolia				o		o					
Galium verum							o				
Galium hercynicum	c	f	f	c	a	a		f	a		f
Bellis perennis							o				
Achillea millefolium						f					
Cirsium palustre							o	o	f		
Leontodon autumnalis		r									
Hieracium pilosella	f		o		o						
Hypochaeris radicata							o				
Juncus squarrosus		r			c		o			o	c
Juncus effusus								o	o		
J. articulatus								c	a		
Luzula campestris	f		f	f	c	f		o	o		
Trichophorum caespitosum										f	
Carex vesicaria								o			
Carex nigra				o							
Carex flava									f		
Carex spp.	r					o					
Molinia caerulea										c	
Sieglingia decumbens				r		r					
Festuca pratensis								r	r		
Festuca ovina	a	a	a	a	a	co D	a	c	a	a	a
Poa pratensis	o				r		f	o			
Poa annua			r			o					

Table 16 (contd.)

	HABITAT										
	1	2	3	4	5	6	7	8	9	10	11
Cynosurus cristatus	r					o			r		
Helictotrichon pubescens				r			r				
Holcus lanatus								f	f		
Holcus mollis	r						f				
Deschampsia flexuosa	a	c	o	c	f				o	o	c
D. caespitosa								f			
Agrostis canina		a		c	c		f	o		f	c
A. tenuis	c	a	c		a	co D		c	a	o	f
A. stolonifera								c	o		
Anthoxanthum odoratum	o	c	f	c	f	a	a	c	c	f	
Nardus stricta			f	r	f	o	c	c	f	c	c
Polytrichum commune								o			
P. juniperinum						o					
Dicranum scoparium			o								
Hypnum cuppressiforme			o								a
Pleurozium schreberi			o	o		o					
Rhytidiadelphus squarrosus			o	o	o	c		o	o		
Hylocomium splendens				f		o			c		
Rhytidiadelphus triquetrus			o	f							
Mnium undulatum									o		

Table 17. Agrostis-fescue grassland

Plants of dry habitats	Plants of moist habitats	Plants of wet habitats	Plants of peaty habitats	Plants of all habitats
Sieglingia decumbens		Juncus effusus	Deschampsia flexuosa	Anthoxanthum odoratum
Deschampsia flexuosa		Juncus articulatus	Molinia caerulea	Nardus stricta
Luzula campestris		Agrostis stolonifera	Trichophorum caespitosum	Galium hercynicum
Calluna vulgaris		Deschampsia caespitosa	Calluna vulgaris	Potentilla erecta
Empetrum nigrum	Holcus lanatus	Cardamine pratensis	Empetrum nigrum	Veronica officinalis
Erica cinerea	Holcus mollis	Cirsium palustre	Vaccinium myrtillis	V. serpyllifolia
Helianthemum chamaecystus	Oxalis acetosella	Ranunculus spp.		
Hieracium pilosella	Trifolium repens			
Leontodon autumnalis				
Lotus corniculatus				

Type D: Bracken Table 18. p.117.

Many small areas appear in the outer ring of the map, often as fingers bordering the streams and running right up into the hill masses, or as roughly circular patches in hollows amonst heather communities. They range from 700 ft. to 1,300 ft. mainly in the lower reaches. Bracken clothes the moderate to steep slopes of many valleys especially where the landform is concave, although it also appears on convex slopes which are moderate or less in angle.

In species composition the community bears a strong resemblance to a rather poorer moist agrostis-fescue community and is probably derived from the invasion of such types by the fern (Table 18 p117.) It favours similar sites and soils and the shading by the fronds is sufficient to explain the paucity of species, their low frequencies, and the appearance of woodland plants like Anemone nemorosa. Often up to 90% of the ground is bare or litter covered below the fronds.

From autumn when the fronds are cut back by frost till late spring when they grow up again the sheep often find good grazing in Bracken dominated areas (Photo. 13). In summer they turn their attention to other vegetation types.

Bracken frequently borders on Callunetum, usually where the slope or the drainage changes sharply as at the crest of a ridge or in a wide depression around a spring (Photos. 10 and 11).

Table 18. Bracken: Type D

	Soil types				
	1	2	3	4	5
Pteridium aquilinum	D	D	D	D	D
Juniperus communis	o				
Ranunculus repens			o		o
Viola riviniana	o	o		o	o
Polygala serpyllifolia					o
Oxalis acetosella	a		f	o	
Potentilla erecta	r	f	c	c	f
Fragaria vesca				o	
Chamaenerion angustifolium		o			
Rumex acetosa				r	
Calluna vulgaris					o
Erica cinerea					o
Vaccinium myrtillus	r				c
Veronica officinalis		o			
Veronica chamaedrys				o	
Ajuga reptans				o	
Campanula rotundifolia	o			o	o
Galium hercynicum			a	f	f
Galium verum		o			o
Achillea millefolium					r
Cirsium palustre		o		o	
Luzula campestris			o	r	r
Carex spp.				f	o
Festuca ovina			c	a	a

Table 18 (contd.)

	Soil types				
	1	2	3	4	5
Poa pratensis				o	
Holcus mollis	a				
H. lanatus			c	f	
Deschampsia flexuosa	c				c
Agrostis canina	o	o	f		
A. tenuis		o	a	c	c
Anthoxanthum odoratum		o	c	f	o
Dicranum scoparium			o		
Pleurozium schreberi				r	
Rhytidiadelphus squarrosus			c	r	o
Hylocomium splendens					o
Mnium hornum			o		

Soil types

1, 2 Freely drained brown forest soil

3, 4, 5 Slightly poorly drained brown forest soil

Table 19 *Calluna vulgaris* heath

	Communities							
	1	2	3	4	5	6	7	8
Pteridium aquilinum	o							
Helianthemum chamaecystis	o							
Genista anglica						o		
Lathyrus montanus	o							
Potentilla erecta	o		r			c	f	f
Calluna vulgaris	a	D	D	D	D	D	D	D
Erica cinerea	c	o				c		
Vaccinium myrtillus	f	f	f	o	o	f	c	
Empetrum nigrum	r				r	o		
Veronica serpyllifolia	o							
Viola riviniana	r							
Campanula rotundifolia	r							
Galium hercynicum	f							
Hypochaeris radicata	o							
Luzula campestris	o						o	
Juncus squarrosus					o		o	
Trichophorum caespitosum						o		
Carex nigra						o		
Carex spp.						o		
Festuca ovina	f			c		c	c	a
Deschampsia flexuosa	f	o	c	o	c		c	a
Agrostis tenuis	c		o			o	o	
Nardus stricta	r	r		o	o	c	c	f
Polytrichum juniperinum	r							
Hypnum cupressiforme						o		o
Rhytidiadelphus splendens	o							

Soils

Communities 1, 2 and 3	Shallow podzol with very well drained upper horizons
Communities 4, 5 and 6	Podzol with freely drained upper horizons
Communities 7 and 8	Podzol with less well drained upper horizons

Type P: Calluna vulgaris heath Table 19 p 119

Vegetation type P occurs in medium to large sized blocks in the outer ring, being most extensive at the southern part of both Spartleton and Monynut Edges. It covers moderate to steep hill slopes at levels from 750 ft. to 1,300 ft. with all aspects and generally in more exposed positions. It is typically a dense cover of short compact ling heather of more even height than any other type with shoots of Vaccinium myrtillus or Deschampsia flexuosa pushing through the branches at the rate of approximately one or two shoots per 100 sq. cm.

Table 19 gives species lists for eight habitats ranging from steep slopes and excessively dry on the left side to gentler topography and wetter soils on the right. List No. 1 came from a very steep near scree slope with clumps of short Calluna and E. cinerea and patches of agrostis-fescue grassland. Several of the subsidiary species colonised the many patches of bare soil. The other lists are from closed communities. Noteworthy is the rise in numbers of "wet heath" species, Nardus stricta, Juncus squarrosus, Trichophorum caespitosum, towards the right hand side of the table, showing the relation of this type to types J, T and U.

Table 20. Calluna - Vaccinium myrtillus p122

	Dod Hill	Black Law
Blechnum spicant		o
Viola riviniana	o	
Potentilla erecta	c	c
Calluna vulgaris	va	coD
Erica cinerea	o	
Vaccinium myrtillus	D	coD
Campanula rotundifolia		o
Galium hercynicum	c	a
Hieracium pilosella	r	
Juncus squarrosus		o
Luzula campestris	o	f
Carex nigra	o	
Festuca ovina	f	o
Deschampsia flexuosa	c	f
Agrostis tenuis	c	f
Polytrichum juniperinum	o	
Dicranum scoparium	o	
Hypnum cupressiforme	o	f
Plagiothecium undulatum	f	o

Type V: Calluna - Vaccinium myrtillus Table 20 p121

At many places on the area, small patches of this type can be found, but only at two places, Dod Hill (Ref. 73/68) and Black Law (Ref. 71/65) are they large enough to be shown on the map. The community occurs between 850 ft. and 1,100 ft. usually on very steep slopes with either convex or concave landforms and a certain distance from the crest so that drainage water from above percolates through the soil. Most sites have a northerly or easterly aspect and are very exposed.

The vegetation is a low scrub of Vaccinium myrtillus and Calluna vulgaris with grasses and herbs pushing their shoots through the bushes. It might be regarded as a marginal type of Calluna heath for it is often found bounded by types P or J on the less steep slopes above and types D or K on the wetter sites below. It has also affinities with scree vegetation but its soil is more stable (Table 20).

Type J: Calluna mixed heath

Type T: Calluna - Nardus stricta Table 21 p125

Type U: Calluna - Trichophorum caespitosum

This closely related group occurs in medium to large sized blocks which form a ring or broad band along the outer parts of the map. Type J is the most extensive. There are nine sites occupied by type T, the largest being at Gullion's Cleuch Rig, Burnhope Rig, Berry Hill and Peat Law all towards the east of the region. Only one site is occupied by Type U, the nearly level top of Hall's Edge. All are on gentle to moderate slopes on the shoulders of hills; the low rigs between cleughs at the head of Bothwell Water or sometimes on steep slopes with a concave topography. Type J occurs between 800 ft. and 1,325 ft., type T between 875 ft. and 1,200 ft., mostly about 1,000 ft., and type U at 1,100 ft. They face every direction and are mostly in exposed places.

The group is characterised by the dominance of Calluna, which forms a larger and more uneven scrub than in type P. Subsidiary species are greater in number and density, often forming colonies such as the clumps or rings of Juncus squarrosus or the patches of Nardus dominated grassland in hollows. The most constant species are Vaccinium myrtillus, Juncus squarrosus, Deschampsia flexuosa and Trichophorum caespitosum, with Nardus stricta, Erica tetralix and Festuca ovina in the next rank. The mosses are also frequent in occurrence, probably because the larger, more open bushes provide a more congenial habitat than the low, even forms of type P.

Type T is probably a transition between type J and Nardus grassland for not only the dominants but the subsidiary species are intermediate in their frequency. In this type where the land dips slightly below the general level to form a hollow it will contain *Nardus* grassland and where low knolls occur they will bear Bracken (type D). List 7, Table 21, p.125 although representing type J, are really transitions between it and *Eriophorum* bog and *Molinia* grassland respectively.

Type U is distinct in this area for there are no *Trichophorum* bogs in south-east Scotland. The ground is wet or soggy more often and for longer periods than with the other members of the group, and bare patches and clumps of *Leucobryum* are frequent.

Table 21. Species composition of Calluna-dominated communities

Community -	1 J	2 J	3 J	4 T	5 T	6 U	7 U	8 C.Er.	9 C.Mol.
Oxalis acetosella					r				
Trifolium repens					r				
Potentilla erecta	o	o	f	f	c		r		
Calluna vulgaris	D	D	D	D	a	D	co D	D	D
Erica cinerea		o							
Erica tetralix			f				f	o	c
Vaccinium myrtillis	o	f	o	coD	o	o		f	o
Empetrum nigrum	o	o					r		
Galium saxatile		f	o				r		
Luzula sylvatica					f				
Luzula campestris			o	o	f				
Juncus squarrosus	o	c	c	c	f	o	f	f	c
Trichophorum caespitosum		o	o	r		a	co D		f
Eriophorum angustifolium									o
Eriophorum vaginatum								c	
Carex nigra	c					f		o	
Carex spp.			o				o		
Festuca ovina		o	f	a	c			o	
Deschampsia flexuosa	f		o	c	c	o	o	o	
D. caespitosa					o				
Agrostis canina				o	o		o	r	
A. tenuis			f	o	o				
Anthoxanthum			o				r		
Nardus stricta		c	c	a	a		o		f

Table 21 (contd.)

Community -	1 J	2 J	3 J	4 T	5 T	6 U	7 U	8 C.Er.	9 C.Mol.
Molinia caerulea			r			o			a
Polytrichum commune	c				f	o		o	
P. juniperinum		o		o			o		
Dicranum scoparium	o							o	
Hypnum cupressiforme	o	o	f	o				c	
Pleurozium schreberi			o	c	f		f		
Rhytidiadelphus squarrosus	o				o				
Hylocomium splendens	f	o	f		o		f		
Mnium hornum	o								
Plagiothecium undulatum	o	o						o	
Leucobryum glaucum		o	o		r	f	o		
Sphagnum spp.	o	r					o		

J = _Calluna_ mixed heath

T = _Calluna_ - _Nardus stricta_

U = _Calluna_ - _Trichophorum caespitosum_

C.Er = _Calluna_ - _Eriophorum vaginatum_

C.Mol = _Calluna_ - _Molinia caerulea_.

Table 22. Calluna - Eriophorum vaginatum - Sphagnum spp. - Type O p128

	1	2	3	4
Potentilla erecta				r
Calluna vulgaris	Co-D	Co-D	Co-D	Co-D
Erica tetralix	f	o		o
Vaccinium myrtillus	r		c	f
Empetrum nigrum		o	r	
Galium saxatile				o
Pinguicula vulgaris		o		
Drosera rotundifolia		r		
Luzula campestris			o	o
Juncus squarrosus	o	r		f
Trichophorum caespitosum			o	
Eriophorum vaginatum	Co-D	Co-D	Co-D	Co-D
Eriophorum angustifolium			r	
Carex nigra			c	
Carex spp.	o	o	o	f
Festuca ovina				o
Deschampsia flexuosa			o	
Agrostis canina				r
Nardus stricta				r
Molinia caerulea				r
Polytrichum commune	o		o	f
Pleurozium schreberi		o		
Hylocomium splendens		o	r	o

Lists 1 and 2 Communities subject to grazing only

Lists 3 and 4 Communities recently subject to burning and partial drainage.

Table 22 (contd.)

	1	2	3	4
Rhytidiadelphus loreus		r		o
Mnium hornum			r	
Plagiothecium undulatum	o			r
Sphagnum spp.	f	a	o	o

Type O: Calluna - Eriophorum vaginatum - Sphagnum spp.

Several small to medium sized areas occur along the crests of all three ridges and at the edge of the shallow basin to the south of the escarpment. Ranging in altitude from 950 ft. to 1,500 ft. most of the community is above 1,100 ft. Two types of site are commonly occupied by this vegetation, the first being the almost flat slightly convex tops of the long rigs and shoulders at higher levels and the second the fairly wide shallow basins with slow drainage at the head of the larger streams. Aspect has no effect and the community lies in the most exposed places.

The community is a mixed one dominated by Eriophorum vaginatum and Calluna vulgaris with Sphagnum spp. in varying densities. The other species are those characteristic of moorland and heath and vary in frequency according to the recent history of the site. The type is derived from true hill peat or basin peat by burning, grazing, draining and cutting turf for fuel. Lists 1 and 2 in Table 22 are from bogs which had not been interfered with for many years and lists 3 and 4 from sites subject to regular burning and on which the ditches had been kept clear. Eriophorum vaginatum is a valuable plant on hill ground, providing most of the spring "meat" for sheep and, according to the shepherds, its presence in the diet is essential for the milk flow after lambing. The good shepherd diligently burns the bogs to ensure an adequate supply of the soft white succulent stems throughout the years.

The most closely related types are J and P and in fact the sequence of types over an area frequently runs P, J, O. The most frequent boundary is with type J but where conditions change sharply type J may be missing or in a strip too small to be shown and the boundary is with type P. In one case where the bog lies directly above a steep slope on Bothwell Hill, parts of the peat are slowly sliding down and the vegetation is of a mixed type. In one or two places where the relief is low the boundaries are with type K (Juncus articulatus - Nardus grassland or flush) or with type M (Molinia grassland), most usually at lower levels and on the edges of a wide drainage basin. The type occurring in basin sites is often bounded by type L (Juncus communis) and in a few places by type K or type N (Nardus grassland).

Type K: Juncus articulatus flush grassland. Table 23 p. 131.

Small patches are scattered irregularly over the central region of the map. The altitudinal limits are 800 ft. and 1,200 ft. with the majority of occurrences between 1,000 ft. and 1,150 ft. It covers the bottoms of small shallow valleys and low hollows where the water percolates readily through the soil to nearby streams.

The community appears as a bright dark green patch on the hill splashed with the colours of many herbs during late spring and summer. It ranges from a dense stand of Juncus articulatus with herbs such as Lychnis flos-cuculi, Nasturtium officinale, Scabiosa succisa, Parnassia palustris and grasses such as Poa pratensis in the wettest places to a mixed Nardus grassland with Juncus articulatus as a physiognomic dominant. Galium hercynicum and Potentilla erecta displace many of the herbs, and grasses like Deschampsia flexuosa and Festuca ovina enter.

The most frequent boundary is with type L (Juncus communis) due to an increasing wetness of the soil. It is also frequently bounded by Molinietum (type M) with which it shares the ~~a preference for~~ poorly drained soils but Molinia grows on a peaty topsoil while Juncus articulatus grows on a mineral topsoil. It merges into Nardus grassland (type N) towards more free soil drainage. Where conditions change sharply boundaries with types P, J and O occur.

Because of its moderately sized rhizomes, Juncus articulatus does not form tussocks but rather an even stand, varying in density.

Table 23. Juncus articulatus flush grassland: Type K
P. 130.

Sample lists –	1	2	3	4	5	6	7
Ranunculus repens	o	o		o	f		f
R. acris	f		o			o	r
R. flammula	o		o				
Cardamine pratensis	f	o		o	r		r
Nasturtium officinale	o	f				r	
Viola riviniana				f			f
Hypericum tetrapterum	o		f				o
Lychnis flos-cuculi	c	r					
Oxalis acetosella				r			
Trifolium repens	o	f	f		c	o	f
Lotus uliginosus	f	r		o			o
Lathyrus montanus	r			f		o	r
Potentilla erecta				f	c	c	f
Parnassia palustris	o						
Rumex acetosa	f	o					r
Veronica officinalis					c		o
Veronica chamaedrys	o						
Pedicularis palustris							o
Rhinanthus crista galli							o
Mentha aquatica	l						
Plantago lanceolata	o						f

Table 23 (contd.)

Sample lists-	1	2	3	4	5	6	7
Galium hercynicum			c	f	a		c
Galium palustre	f						
Succissa pratensis	o						f
Cirsium palustre	f	o	o	o	f	o	o
Juncus squarrosus						r	f
Juncus communis	o	o	f	o	r		
Juncus articulatus	D	D	a	a	a	c	a
Luzula campestris				o	o	o	o
Carex spp.	o		o		f		f
Carex vesicaria	f			o		c	o
Carex pulicaris	r					r	o
Carex echinata	f						
Festuca pratensis	o	o	o	r	r		o
Festuca ovina	f	f	f	c	c	a	c
Poa trivialis						o	
Poa pratensis	f	o	f				o
Cynosurus cristatus	o					f	f
Heliotrichon pubescens						o	o
Holcus lanatus	o	c	c	f	f	c	c
Deschampsia flexuosa					o		f
D. caespitosa	r		o	f		o	
Agrostis canina	f		c	o		c	c
A. tenuis	o	o	f	c	c		c
A. stolonifera	c	c		c	o		r
Anthoxanthum odoratum	f	a	f	c	c	f	c

Table 23 (contd.)

Sample lists -	1	2	3	4	5	6	7
Nardus stricta		o		c	f	c	a
Dryopteris filix-mas			o				r
D. spinulosa	o				f		
Polytrichum commune	o			o			o
Brachythecium purum	f	o			f		
Rhytidiadelphus squarrosus	r		f	o	o	o	f
Pleurozium schreberi	f					f	c
Hylocomium splendens	f				c		f
Mnium hornum	r						o
Mnium undulatum	o				o		

Table 24. <u>Juncetum communis:</u> Type L p. 136.

Sample lists -	1	2	3	4	5	6	7
Ranunculus repens	o	f	f	a	o	o	c
R. acris	f		o		f		f
R. flammula		o			o		o
Cardamine pratensis		o	f	f			f
Nasturtium officinale	o		r		f	o	o
Viola riviniana				o			o
Cerastium vulgatum		o	o	f		r	f
Stellaria media	o	o	r		f	r	o
Sagina nodosa				r			r
Trifolium repens	f	c	f	c	f	r	c

Table 24 (contd.)

Sample lists	1	2	3	4	5	6	7
Lotus corniculatus		o				o	r
Lotus uliginosus	o		f			o	o
Vicia cracca		f	f				f
Potentilla erecta				o		o	r
Potentilla anserina		o					r
Erica tetralix						o	
Calluna vulgaris						o	
Rumex acetosa	o		f	o	r		f
Myosotis scorpioides	o	o					o
Veronica chamaedrys				o			f
Prunella vulgaris	o						f
Galium hercynicum		f	f	o	o	f	o
Galium palustre	o				f		r
Galium uliginosum				o			
Succissa pratensis			o				r
Achillea ptarmica		o					r
Cirsium palustre	o	o	f	o			f
Juncus communis	a	D	a	a	D	a	D
J. articulatus	o				o	o	o
J. bulbosus				r			r
Luzula campestris	f	o			f	o	o
Eriophorum vaginatum						r	
Carex nigra			c		c		f
C. echinata			o			r	r

Table 24 (contd.)

Sample lists	1	2	3	4	5	6	7
Carex spp.	o	c	o	f	f	o	f
Festuca pratensis	o						
Festuca ovina	f	f	f	c		f	f
Poa pratensis	o		f				o
Holcus lanatus	c	a	c	c	o	c	c
Holcus mollis					o		o
Deschampsia flexuosa		o	o			o	o
D. caespitosa							o
Agrostis canina	c	a	o		o	f	c
A. tenuis		c	o	f	o	o	f
A. stolonifera			a	f	c	f	c
Anthoxanthum odoratum	o	f	f	f	c		c
Nardus stricta				o		o	o
Polytrichum commune		o			o	c	f
Pleurozium schreberi	f	o		o		f	c
Hylocomium splendens	f	c	f	f	o	f	f
Rhytidiadelphus squarrosus	f	f	c	o	f	o	o
Rhytidiadelphus triquetrus		f	o				o
Mnium hornum				o			f
Mnium undulatum					o		f

Type L: Juncetum communis Table 24 p. 133.

Small patches lie scattered across the map, mostly in the north central area and the south-east corner, at all levels from 700 ft. to 1,200 ft. It occupies flat or gently sloping sites where drainage water collects from above and percolates through the soil to nearby streams, hence is commonest in valley bottoms and places with a concave landform. Another frequent site is along the margin of the basin type of Calluna - Eriophorum bog. Aspect is of no importance and most sites are in less exposed positions.

The vegetation with which it forms natural boundaries are types K, O and M. Boundaries with types D, N, P and J occur where conditions of topography or soil make a sharp change.

Typically this is a wet grassland dominated by big tussocks of Juncus communis. Herbs, grasses and mosses characteristic of wet meadow, such as Ranunculus acris, Cardamine pratensis, Trifolium repens, Cirsium palustre, Carex spp., Holcus lanatus, grow lush between the tussocks. In their dead or dying centres plants more characteristic of dry places such as Potentilla erecta, Galium hercynicum, Festuca ovina, Agrostis tenuis and A. canina, Rhytidiadelphus squarrosus, H. splendens are found. In sites adjacent to bogs the heath species Erica tetralix, Eriophorum vaginatum and others appear as occasional constituents.

Table 25. Molinietum: Type M p.139.

	1	2	3	4	5	6
Potentilla erecta			o	o	o	
Parnassia palustris			o			
Calluna vulgaris					a	
Erica tetralix					o	
Vaccinium myrtillus	o			f	f	f
Empetrum nigrum						o
Galium hercynicum	o		o	a	c	f
Galium palustre	f	f	o	f		c
Narthecium ossifragum		o				
Juncus articulatus			o			
Juncus squarrosus	c	f	f	r	f	c
Luzula campestris	o			o		o
Eriophorum vaginatum			r	o	f	
Trichophorum caespitosum				o	o	
Carex nigra			c		o	f
Carex stellulata						o
Carex spp.	f		o	r		
Molinia caerulea	D	D	D	D	D	D
Deschampsia flexuosa	a	c	a	a	f	
D. caespitosa		o				
Festuca ovina	f	c	c	c	f	c
Agrostis canina		f	o			
Agrostis tenuis					o	
Agrostis stolonifera	f	a	c	f		c
Anthoxanthum odoratum	f			c		f

Table 25 (contd.)

	1	2	3	4	5	6
Nardus stricta		o		f	f	f
Polytrichum commune	a	o	a			c
P. juniperinum					o	
Dicranum scopasium					o	
Hypnum cupressiforme						o
Pleurozium schreberi			o			
Hylocomium splendens		o	o			o
Mnium hornum	o			o		
Mnium undulatum	o					
Plagiothecium undulatum	o					o
Sphagnum spp.	f			o		

Communities 1, 2 and 3 are from _Molinia_ grassland.
Communities 4 and 6 are _Nardus_ - _Molinia_ grasslands.
Community 5 is a _Calluna_ - _Molinia_ heath.

Table 26. The species of Molinia grassland which are confined to one type of species list

Lists 1, 2 and 3	Lists 4 and 6	List 5
Parnassia palustris	Vaccinium myrtillus	Calluna vulgaris
		Erica tetralix
Narthecium ossifragum	Empetrum nigrum	
	Galium hercynicum	
Juncus articulatus	Trichophorum caespitosum	
Deschampsia caespitosa	Agrostis tenuis	
Agrostis canina	Carex stellulata	

Type M: Molinia grassland Table 25 p 137

A large block occurs in the middle of the map, three smaller areas a little to the north of it and four in the south-east corner. They lie between 900 ft. and 1,200 ft. The sites vary from shallow, wide gently sloping basins draining into streams to low flat-topped ridges bordered by streams on each side.

Most of the sites bear a smooth undulating sward of grasses. Two, which abut on Calluna - Eriophorum bogs, have a tussock habit and a high frequency of Calluna vulgaris for a long way in from the boundary. Lists are given in Tables 25 and 26 to show the variety of the community. Columns 1, 2 and 3 represent the species composition of typical smooth swards and show by the presence of Parnassia palustris, Galium palustre and Juncus articulatus, some affinity with type K. Lists 4 and 6 of Table 25 are for Molinia - Nardus grassland which will be described later. List 5 is for Calluna - Molinia grassland from Dogbush Know (Ref. 68/67). The presence of Calluna, Erica tetralix and other species characteristic of Calluna moor should, according to Rutter (1955) be due to a drier soil than usual while the presence of tussocks according to the same author should indicate greater fluctuation in the water table. This particular area is less well drained than in the sward type, and the summer water table is higher. A part of the explanation may lie in the fact that water from the Eriophorum bog seeps down the slope through the Molinia peat or just below it.

The Lammermuir Molinietum is a more mixed community than that of the Moorfoots or the Cheviots. This is perhaps due to the lower elevation and smaller rainfall.

Table 27. <u>Nardetum</u>: Type N p143

Soil types -	C	D	K	P	J	M
Pteridium aquilinum		r				
Blechnum spicant				o		
Dryopteris spinulosa			r		r	
Ranunculus repens			o			
Viola canina	o		o			
Polygala vulgaris	r					
Oxalis acetosella		o			o	
Potentilla erecta	c	f	a	f	f	o
Trifolium repens		o	o		o	
Lotus corniculatus	f					
Vicia sepium		o	o			
Lathyrus montanus			o			
Rumex acetosa	r			r		
Calluna vulgaris					o	o
Erica cinerea				o	o	
Vaccinium myrtillus		a	c		f	
Empetrum nigrum						
Veronica officinalis	o					
V. chamaedrys			o			
Thymus drucei	r		o			
Plantago lanceolata			f			
Campanula rotundifolia	o					
Galium hercynicum	c	c	c	c	c	a
Achillea millefolium			o			
Cirsium palustre			o			

Table 27 (contd.)

Soil types -	C	D	K	P	J	M
Juncus squarrosus		o	o	o	f	a
Juncus articulatus			o			
Juncus communis			o			
Luzula campestris	c	f		f	o	f
Luzula sylvatica					f	
Trichophorum caespitosum					o	
Carex nigra			f			
Carex ovata			r			
C. echinata			r			
C. vesicaria			f			
Carex spp.			o			
Molinia caerulea				o		
Festuca ovina	c	a	a	a	c	c
Poa annua	o	r				r
Poa trivialis		o	o			
Poa pratensis	o		o			
Holcus lanatus	r		f			
Holcus mollis			o			
Deschampsia flexuosa	c	f	f	a	c	c
D. caespitosa			o			
Agrostis canina	o	o	o	f	f	o
A. tenuis	c	c	a	c	c	f
A. stolonifera			f			
Cynosurus cristatus		o			r	
Anthoxanthum odoratum	o	c	c	c	c	f

Table 27 (contd.)

Soil types -	C	D	K	P	J	M
Nardus stricta	a	D	D	D	D	a
Sieglingia decumbens				r		
Polytrichum commune			1f		1f	f
P. juniperinum		f				
Dicranum scoparium	o					
Hypnum cupressiforme						o
Rhytidiadelphus squarrosus	f	c	f	f	f	a
Pleurozium schreberi		f	o	o	o	o
Hylocomium splendens		f	f		o	c
Rhytidiadelphus squarrosus						
Plagiothecium undulatum		o			o	
Mnium hornum		r				
Leucobryum glaucum					o	
Sphagnum spp.					o	o

Type N: <u>Nardus</u> grassland Table 27 p.141.

Small to medium sized patches are scattered throughout the area on a variety of sites and at all levels up to 1,500 ft. The usual range of topography is from gentle convex to steep concave slopes, but less frequently, yet not rarely, it may be found on any landform including the steepest. Sheltered and very exposed positions are all to be found occupied by <u>Nardeta</u>.

<u>Nardus stricta</u> is a grass with a very wide

tolerance of environmental conditions and a greater resistance to burning and grazing than the majority of hill plants. When it occupies ground extensively it can form a thick mat of dry dead material which effectively keeps out many other plants. These features allow it to colonise a variety of sites with a sward which, although having a basic pattern of species, will vary in accordance with the alternative type of vegetation for that site. In Table 27 each column represents a species list for a particular soil type. The relations between various types of _Nardetum_ and soil will be discussed in a later section and here only the vegetation will be described.

Nardus grassland presents from a distance an evenly tufted grey green sward. The light straw coloured stools each about six inches to a foot in diameter stand out against a green groundwork of hill grasses and herbs. In the Lammermuirs the dominant rarely covers more than 60% of the ground and often 40%, or less. The community is really a mixed grassland in which _Nardus_ is the species occupying a larger area than any other. The constant species are:

Potentilla erecta	c - f	_Agrostis canina_	f - o
Galium hercynicum	a - c	_Agrostis tenuis_	a - c
Festuca ovina	a - c	_Anthoxanthum odoratum_	c - o
Deschampsia flexuosa	a - f	_Rhytidiadelphus squarrosus_	a - f

Less constant are:

Juncus squarrosus a - o

Luzula campestris c - o

Pleurozium schreberi f - o

Hylocomium splendens c - o

This is in close agreement with the lists given by Smith (1918) for *Nardeta* in the Moorfoot Hills and King (1955) for those in the Cheviot Hills. The other species tend to segregate out according to the soil type on which they grow and are shown grouped in Table 29, p.149. It is clear from this that those on podzolic soils are also found in vegetation types P, J and T while those on brown forest soils also occur in types C and D, and those on the gley soils also occur in vegetation types K and L.

Nardus grassland shares boundaries with every type of vegetation. The transition type T between type N and types J and P has been discussed as has the transition to type K. The success of *Nardus* in displacing other vegetation is probably due to biotic factors, especially burning and grazing intensively on leached soils poor in minerals (King 1955). Although the Lammermuirs are probably the most fertile sheep-grazing lands in Britain they are also the most intensively used. Environmental conditions are thus favourable for the spread of this community.

Type MN: Molinia - Nardus grassland Table 28 p.147.

A community intermediate between type M and type N covers several large blocks in the central region. It occurs between 800 ft. and 1,100 ft. on sites similar to that of Molinia grassland and may be derived from it by management favouring the invasion of Nardus.

The vegetation is a sward rougher than Nardus grassland and more tufted than Molinietum. Subsidiary species, which occupy a large proportion of the ground, show its affinities with wet heath and damp grassland. It is a transition type but covers so large an area that it had to be recognised as a distinct vegetation type. The reason for its wide occurrence may be partly due to climate in that the area is drier than most hill land in south-east Scotland and partly biotic in that this is the most intensively used hill land in Britain.

Table 28. Nardus - Molinia grassland: Type MN p.146.

Dryopteris filix-mas	r
Viola riviniana	r
Potentilla erecta	f
Lotus corniculatus	o
Lathyrus montanus	o
Vicia sepium	r
Calluna vulgaris	o
Erica tetralix	r
Vaccinium myrtillus	f
Empetrum nigrum	r
Veronica officinalis	o
V. chamaedrys	r
Galium hercynicum	a
G. palustre	o
Juncus squarrosus	c
Luzula campestris	f
Trichophorum caespitosum	r
Carex nigra	f
Carex spp.	o
Molinia caerulea	a
Festuca ovina	c
Poa pratensis	r
Holcus lanatus	o
Deschampsia flexuosa	c
Agrostis canina	c

Table 28 (contd.)

A. tenuis	f
A. stolonifera	f
Cynosurus cristatus	r
Anthoxanthum odoratum	c
Nardus stricta	a
Polytrichum commune	lf
Dicranum scoparium	f
Hypnum cupressiforme	o
Rhytidiadelphus squarrosus	f
Pleurozium schreberi	r
Plagiothecium undulatum	o

Composite list from several sites

Table 29. The relationship of the subsidiary species of <u>Nardus</u> grassland to soil type

<table>
<tr><th colspan="2">Podzols</th><th colspan="2">Brown earths and gleys</th></tr>
<tr><th>Dry</th><th>Wet</th><th>Dry</th><th>Wet</th></tr>
<tr><td>Blechnum spicant</td><td></td><td>Pteridium aquilinum</td><td>Ranunculus repens</td></tr>
<tr><td>Erica cinerea</td><td></td><td colspan="2">Viola canina</td></tr>
<tr><td></td><td></td><td>Polygala vulgaris</td><td></td></tr>
<tr><td colspan="2">Calluna vulgaris</td><td></td><td></td></tr>
<tr><td></td><td>Polytrichum commune</td><td colspan="2">Oxalis acetosella</td></tr>
<tr><td></td><td></td><td colspan="2">Trifolium repens</td></tr>
<tr><td></td><td>Luzula sylvatica</td><td>Lotus corniculatus</td><td></td></tr>
<tr><td></td><td>Trichophorum caespitosum</td><td colspan="2">Lathyrus montanus</td></tr>
<tr><td></td><td>Molinia caerulea</td><td>Veronica officinalis</td><td></td></tr>
<tr><td></td><td></td><td>Thymus drucei</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Plantago lanceolata</td></tr>
<tr><td></td><td></td><td>Campanula rotundifolia</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Achillea millefolium</td></tr>
<tr><td></td><td></td><td></td><td>Cirsium palustre</td></tr>
<tr><td></td><td></td><td></td><td>Juncus articulatus</td></tr>
<tr><td></td><td></td><td></td><td>Juncus communis</td></tr>
<tr><td></td><td></td><td colspan="2">Poa pratensis</td></tr>
<tr><td></td><td></td><td></td><td>Holcus lanatus</td></tr>
</table>

Table 29 (contd.)

Podzols		Brown earths and gleys	
Dry	Wet	Dry	Wet
		Holcus mollis	
			Polytrichum commune
			Deschampsia caespitosum
			Agrostis stolonifera

Table 30. Screes: Type S p.153.

	1	2	3
Pteridium aquilinum		o	f
Blechnum spicant			o
Athyrium filix-femina	r		
Dryopteris filix-mas	o	o	
Helianthemum chamaecystis			o
Viola riviniana		o	
Potentilla erecta		o	f
Calluna vulgaris	r		f
Erica cinerea		o	o
Vaccinium myrtillus	o	f	c
Rumex acetosella	o	c	
Thymus drucei		r	o
Digitalis purpurea		o	
Tuecrium scorodonia	o	f	f
Euphrasia officinalis		r	
Veronica serpyllifolia			o
Campanula rotundifolia			o
Galium saxatile	o	f	f
Hypochoeris radicata		o	o
Crepis capillaris			o
Hieracium pilosella	r	o	
Luzula campestris	r		o
Carex spp.			o
Festuca ovina	o	c	c

Table 30 (contd.)

	1	2	3
Deschampsia flexuosa	o	c	c
Aira caryophyllea	o		
Agrostis canina		r	
A. tenuis	r	f	f
Nardus stricta		o	
Polytrichum juniperinum	o	o	o
P. urnigerum	o	o	
P. formosum			o
Rhacomitrium lanuginosum	f	o	
R. heterostichum	o		
Dicranum spp.	r		f
Pleurozium schreberi	r		o
Rhytidiadelphus squarrosus		o	
R. loreum			o
Hypnum cupressiforme			o
Hylocomium splendens		o	f

1. Small stones and rock rubble, very unstable.
2. Colluvial scree of fine materials, fairly stable.
3. Boulders and stones, partly stable.

Type S: The vegetation of screes Table 30 p.151.

A wide range of vegetation, influenced by the nature of the soil material, the angle of the slope and the bordering vegetation, grow on steep unstable hill slopes.

The recently eroded boulder clay at the head of many valleys bears no vegetation apart from a few turves which are sliding rapidly downhill from the hill mass above. In summer these slopes are dry and apparently stable but in winter the surface is a soft sticky mass which oozes downhill most of the time and flows during rainstorms. Eventually they reach an angle of stability and develop a type C or type D vegetation.

The rocky screes derived from the smaller broken stones carry a sparse cover of grasses, ferns, herbs and a few heaths. Vaccinium myrtillus is more frequent than Erica cinerea which in turn is more frequent than Calluna. Dryopteris filix-mas and Pteridium aquilinum are the most frequent ferns present, the former in small clumps and the latter as isolated clusters of two or three fronds. Herbs and grasses occur as isolated tufts or rosettes.

The bouldery screes are the most likely to be covered by a stable vegetation type. It is often heathy as in the example cited in column 3 of the species list, but may bear Birch scrub as at the Bell

Wood (Ref. 67/63) or Oak wood as on the south-west slopes of Crichness Law (Ref. 67/66). In all the sites the pioneer mosses and lichens are to be found on the most unstable places.

Many of the less steep slopes bear a type of vegetation intermediate between true scree and the adjacent types. These have been marked with the letter S prefixing the related vegetation symbol. Type SD, a bracken covered scree is found in the cleuch between Yearn Gill Knowe and Shot Crib Rig (Ref. 71/67) and in nearby areas. Type SP, a Calluna dominated scree and type SO on the slopes of Birk Cleuch Hill (Ref. 66/65). The latter is an area of steep concave slope below a flat plateau bearing type O from which turves and blocks of peat slip over the edge and down the slope very slowly to produce a boggy scree.

On the slope of Spartleton hill bare rock rubble alternates with patches of dried peat and pockets of type C soil. The vegetation is a mosaic of Calluna heath, agrostis-fescue pasture and gorse bushes denoted by the letters SPCg. Rabbit grazing was intensive on the grass and the bushes and their burrowing increased the instability of the soil. Since their destruction by myxomatosis the vegetation has covered over most of the bare patches.

To the west of Hartside (Ref. 65/72) is a region of rugged topography created by the action of melt-water during the ice age. This is a complex mixture of C, D and S vegetation types.

Table 31. Woodland: Type W , p. 158

	1	2	3
Juniperus communis			r
Ulex europaeus		r	f
Sorbus aucuparia	o	o	f
Ulmus glabra	o		
Betula verrucosa	o	a	D
B. pubescens	o		
Alnus glutinosa	c	a	
Corylus avellana	o	o	r
Quercus petraea	D	r	
Salix spp.	r	f	r
Pteridium aquilinum		f	f
Phyllitis scolopendrium	r		
Dryopteris filix-mas	f		f
D. spinulosa	o		o
Thelypteris phegopteris	o	o	f
T. dryopteris	o	f	
Ranunculus acris	r	f	
Anemone nemorosa	c		o
Viola riviniana	o		c
Oxalis acetosella	c	c	c
Vicia sepium		o	
Potentilla erecta			o
Geum urbanum	r	o	
Urtica dioica		r	
Rumex acetosa		f	

Table 31 (contd.)

	1	2	3
Primula vulgaris	c	r	o
Digitalis purpurea	f	r	f
Veronica officinalis			o
V. chamaedrys	r	c	o
Tuecrium scorodonia			c
Ajuga reptans	f		f
Campanula rotundifolia			r
Galium cruciata	r	o	
Galium verum		o	
G. hercynicum			o
Senecio jacobea	r		
S. sylvaticum			o
Luzula sylvatica		lo	
L. campestris			o
Dactylis glomerata		o	
Arrhenatherum elatius		a	
Holcus lanatus		f	
H. mollis	r		
Festuca ovina			o
Deschampsia flexuosa			f
Agrostis tenuis			o
A. canina			o
Anthoxanthum odoratum			c

1. Oakwood - moist to dry.
2. Birch - alder wood - moist.
3. Birch wood - dry.

Type W: Woodland Table 31, p.156.

Natural or semi-natural scrub and woods are found all over the area, usually as bordering strips to steep-sided cleughs and rocky gorges where they are safe from fire, sheep and rabbits. At Sheeppath Glen (Ref. 69/70) and the Rammer Wood (Ref. 64/72) where the slope is less steep and the subsoil a light friable loam the dominant tree is a rather low growing scrubby representative of Quercus petraea with occasional elms, some birch fringing the upper side and a few alders and willows in the very wet places near springs. The underflora is limited and consists of a number of vernal and woodland herbs with ferns and grasses separated by much bare ground. On moist or wet slopes a scrub of alder and willow with a few oaks occupy the ground along with a richer and more complete ground flora consisting of a sward of grasses, sedges, herbs and ferns.

Birchwood (type Wb) holds the drier slopes and rocky ravines with rowan, alder, juniper and gorse. The ground flora is sparse and heathy in character.

The only coniferous woodlands (type Wc) are strips of pine, larch or spruce which have been planted for shelter on the hill. The outer line of trees on the south-west side is always stunted but the rest are tall straight trunks up to 30 to 50 ft. high. They all occur between 1,000 ft. and 1,100 ft.

in exposed hill sides. The canopy is dense and the ground layer poor in species and cover. The pinewood occupies land which would otherwise bear a Calluna dominated community while spruce is surrounded by Molinia or Nardus communities.

Mixed Bottomland

As the name suggests this type fills the valley bottoms as a narrow strip on one or both sides of the stream. It varies with the soil texture and the height of the water table. At one time it may have been filled with trees or shrubs but these have been cleared from all but the steepest sites. The major feature is the liability to flooding which prevents its use for cropping but allows some parts to be fenced and used as permanent pasture. This has an Agrostis-fescue community with some lowland species like Poa pratensis, Alopecurus pratensis, Lolium perrenne and wild white clover. Hummocks of sand are dry and bear a Calluna heath. Shingle or sand banks with a sparse vegetation of grasses and ephemerals or annual weeds like Chenopodium album, Papaver rhoeas, Polygonum aviculare are frequent at the end of bends in the rivers. Low areas and old channels bear Nardus grassland, (type N), or rushes (types K or L), and boggy areas with sedges, Caltha palustris and Rancunculus aquatilis appear. Only in the Tay

Burn (Ref. 66/69) is there an area large enough to map. This is a wide basin at the head of the stream filled with type L, Juncetum communis.

Type Cv: Cultivated Land

This type which is left blank on the map usually occurs on banks with moderate slope and free drainage which would otherwise bear a vegetation of type C or type D. Few of the fields are now ploughed and cropped as part of a regular rotation. Many have been tilled many years ago but are now permanent pasture fenced off from the hill. Others have been opened to the sheep and allowed to run back to Nardus or Calluna heath. Some of the fields now in disuse at Millknowe, Zadlee and Beltondod had been cultivated as long ago as the thirteenth century but the lack of good roads has made it unprofitable to use them.

Chapter VI

DISCUSSION

The effect of altitude, aspect and exposure

The information collected during the survey on the conditions of these three features associated with each soil and vegetation type has been brought together in Tables 32 and 33 (p. 162). These give the altitudinal limits, the range of aspects and the degree of exposure of the majority of sites occupied.

Altitude is not important for itself, but for the changes in other factors, some of which directly affect both plants and soils, which it brings about. Increasing height brings an increase in rainfall from 30 inches at 400 ft. to 35 inches at 1,200 ft. in this area. The temperature falls, the amount of sunshine is less and the growing season is shorter. Over the whole of Britain three broad altitudinal zones are recognised for vegetation. The lowland zone from sea level to between 400 and 700 ft. is mainly in farmland, the upland or foothill zone from 700 to 2,000 ft. is semi-natural hill pasture and the montane zone above that is a form of alpine grassland. The subject of this study takes place entirely within the upland zone.

Inspection of Tables 32 and 33 suggests that the various soil and vegetation types fall into three altitudinal groups. The lower group extends from

Table 32. Soil Type and Altitude, Aspect and Exposure

	Range	Range	Degree of Exposure
C	700 - 1150	All	Full to none
D	700 - 1275	All	Moderate - none
P	800 - 1300	All	Exposed
J	600 - 1475	All	Exposed
O	1050 - 1500	All	Full - moderate
K	800 - 1200	All	Sheltered
L	700 - 1250	All	Sheltered - exposed
M	800 - 1200	All	Full - moderate

Table 33. Vegetation and Altitude, Aspect and Exposure

	Range	Range	Degree of Exposure
C	600 - 1200	All	All
D	700 - 1300	All.	Sheltered - moderate
P	750 - 1300	All	Moderate - full
J	800 - 1325	All	Full
T	875 - 1200	All	Full
U	1100 only	All	Full
V	850 - 1100	N. or E.	Fully exposed
O	950 - 1500	All	Fully exposed
K	800 - 1200	All	Moderate - sheltered
L	700 - 1200	All	Moderate
M	900 - 1200	All	Moderate - full
N	600 - 1500	All	All
MN	800 - 1100	All	Moderate - full

600 ft. to 1,200 ft., the mid from 800 ft. to 1,200 ft. and the upper group from 800 ft. to 1,500 ft. In the lower group are soil types C, D and L and vegetation types C and L. The mid group contains soil types K and M and vegetation types D, P, T, U, V, K, M and MN. The upper group contains soil types P and O and vegetation types J and O. Soil type J and vegetation type N occur at all levels.

To the east, on the Coldingham moors which reach no higher than 700 ft., the groups are at correspondingly lower levels while to the west, where the Lammermuirs and Moorfoots reach 2,000 ft., the groups have correspondingly higher limits. This and the rather wide overlapping of the limits of the groups suggest that the grouping is not due to the change in environment accompanying increasing altitude but largely to the natural zonation of soil and vegetation types on hill slopes. It is shown below that each type occupies a definite position on a slope in relation to the others. Naturally those occupying the upper positions appear to be associated with higher altitudes and those occupying lower positions appear to be associated with lower altitudes.

In the case of soil types P, J and O the formation of a thick layer of mor humus or peat on convex slopes depends on the rainfall and the temperature. The higher the rainfall and the lower the temperature, the greater will be the depth of organic matter accumulated. It is possible that soil type O can only appear on such slopes at the higher altitudes, and in this area it never occurs below 1,100 ft. At this stage in the survey, insufficient evidence has been collected to bring out any definite relationships between altitude and the podzolic soils (types P, J, O) or the Calluna vegetation (types P, V, T, U, J, O).

Aspect is important for two reasons. A site facing a particular direction is exposed to the weather from that quarter and sheltered from the opposite direction. Also it partly determines the amount of sunshine received by the soil or vegetation of the site. Northern and eastern slopes are exposed to the full force of winter storms but protected from the drying winds of early summer and autumn which come from the south-west. They receive less sunshine than others and are liable to keep their snow longer than other sites.

Only vegetation type V (Calluna - Vaccinium myrtillus is limited to a particular aspect, the north and east. The work of Smith (1905), Bright (1928) and Metcalfe (1948) has shown that V. myrtillus has a great ability to stand exposure and that it is often most abundant on extremely exposed sites. In this area it occurs extensively on two sites only and there are many other similar places occupied by another community such as type C, P, J or O.

Exposure brings a number of effects to bear upon the plant. Wind, and the rain, snow and hail which it carries, damages the leaves and stems by constantly rubbing their surfaces together. Temperatures are generally lower and more liable to sudden fluctuation in the more exposed places. Plants in sheltered habitats are usually more lush in habit, having softer tissues and longer leaves and stems than those of exposed places. The effect of "conditioning" whereby plants used to lower temperatures become more frost resistant than individuals of the same species enjoying a warmer climate (Levitt 1956) is far less in the sheltered places. The plants in sheltered sites suffer frost damage in the Lammermuir hills about two to three weeks before those which are exposed.

The terms exposed and sheltered have not the same meaning on the hill that they have on low ground. The degree of exposure is far greater and the amount of shelter far less. Sheltered places are small in extent. As the terms are understood in the low ground there are few places apart from the lee side of woods, buildings and stone dykes which would be called sheltered. It is interesting to note, in this connection, that the combined effects of aspect and exposure largely determine the altitudes at which cultivations may be carried out. On Coldingham Moor, which is fully exposed to the north and east winds, the severity of the climate restricts arable farming to below 300 ft. On Lammermuir Edge the aspect is northwards and the head-dykes run between the 600 and 700 ft. contour lines but in the south facing Bothwell and Whiteadder valleys the plough has been taken to 1,000 ft.

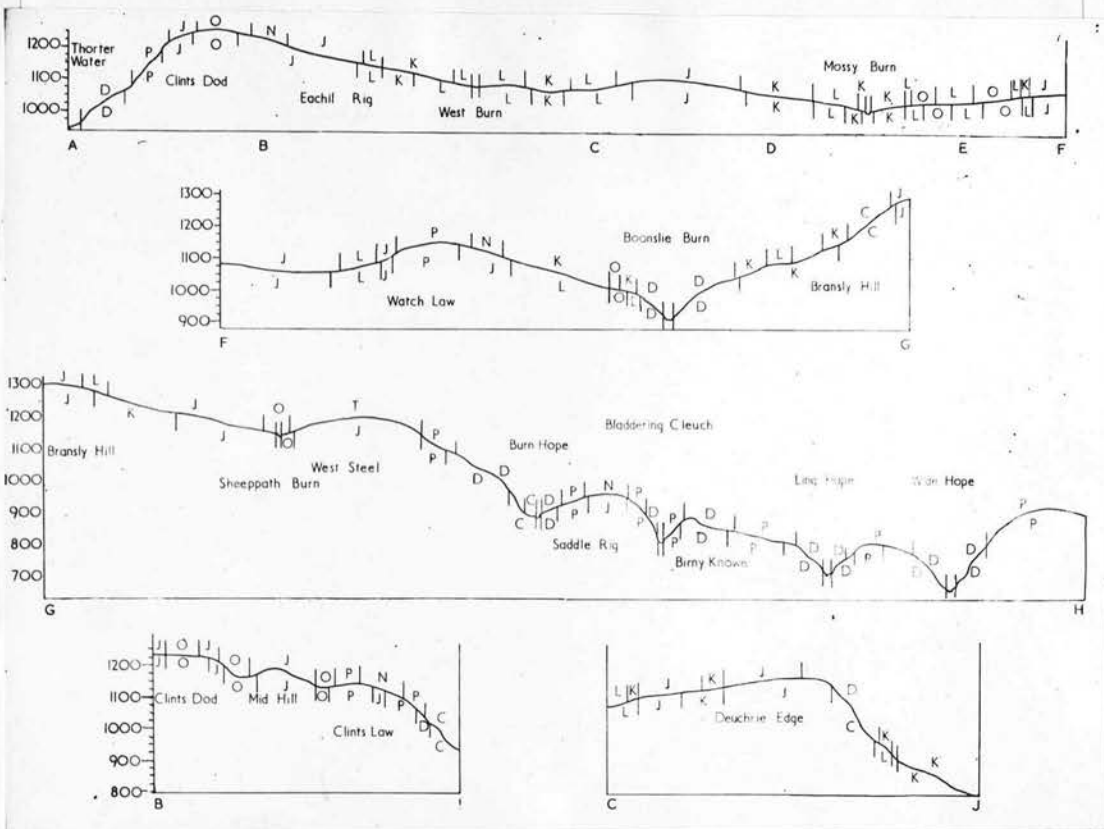
Soil types P, J, O, M and vegetation types P, J, T, U, V, O and M are found on the more exposed sites. Soil types D, K, L and vegetation types D, K, L, MN occupy the more sheltered places. Soil type C and vegetation types C, N and MN occur over a wide range of conditions of exposure. The podzolic soils and the heather dominated vegetation occupy the more exposed places while brown forest and gley soils, grassy, rush or bracken vegetation occupy the more sheltered situations. Naturally the more exposed places are on the upper parts of slopes and the less exposed at the base. The vegetation of the exposed places is that of the upper slopes and the sheltered types are those of the lower slopes. In a primary survey it is impossible to establish a causal relationship between degree of exposure and the occurrence of various soil and vegetation types. It is best at this stage to regard topography as a combination of several factors, among them degree of exposure.

Table 34. Soil type in relation to topography

Soil type.	Degree of Slope	Landform	Position on slope
C	Moderate to steep	Convex Concave	Top. Mid to top
D	Moderate to steep	Slightly concave	Mid
P	Moderate to steep	Convex	Mid and top
J	Gentle to steep	Concave Convex	Mid and top
O	Level to gentle	Concave Convex	Base or lower mid to top
K	Gentle to moderate	Concave	Base to lower mid
L	Level to gentle	Concave	Base
M	Level to moderate	Convex	Lower mid to top
S	Very steep	Any	Base to top
T	Very steep	Any	Base to upper mid
Z	Very steep	Any	Base to upper mid
Cv			
Mb	Flat	Level	Base

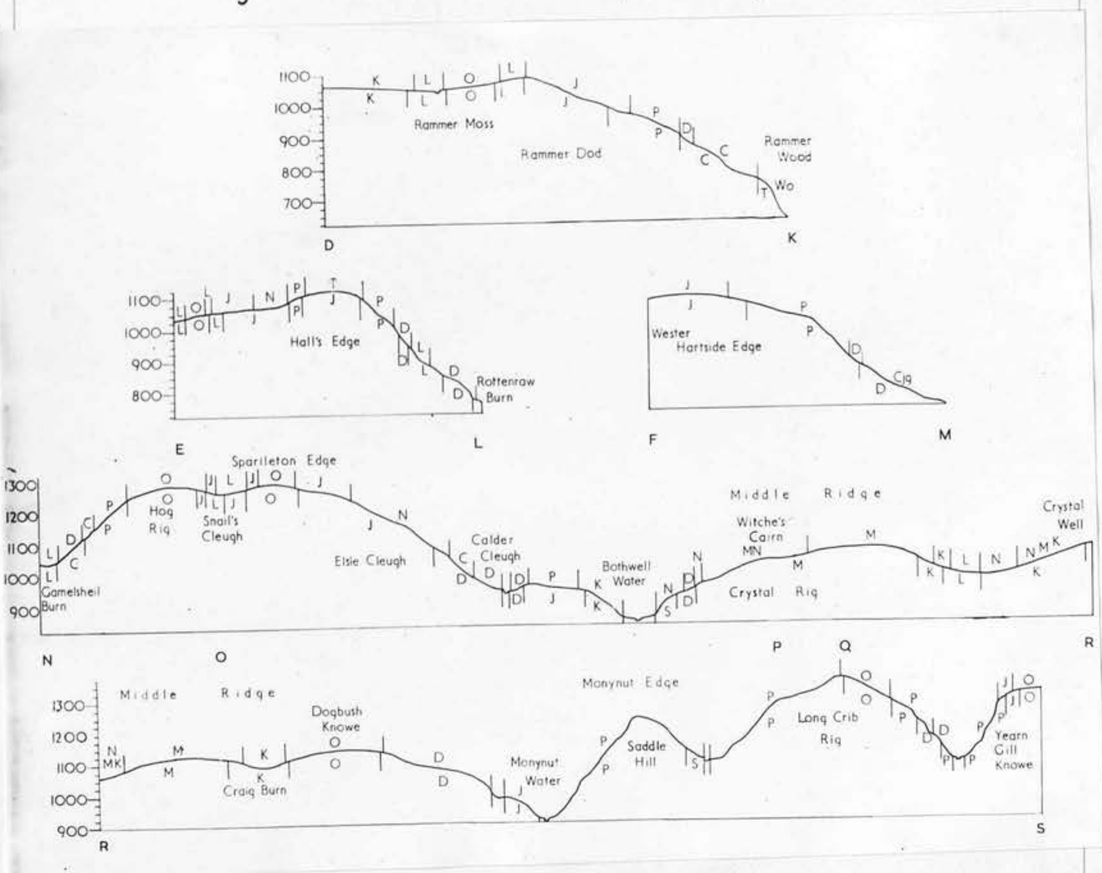
Table 35. Vegetation type in relation to topography

Vgn. type	Degree of Slope	Landform	Position on Slope
C	Moderate to steep	Concave to convex	Bottom to top
D	Moderate to steep Gentle to moderate	Concave Convex	Mid sometimes bottom
P	Moderate to steep	Convex	Mid to top
J	Gentle to moderate Steep	Convex Concave	Lower mid to top
T	Moderate to steep	Concave	Lower mid to top
U	Level	Almost level Slightly convex	Top
V	Very steep	Any	Upper mid
O	Level - gentle	Convex Concave	Top Bottom
K	Level to moderate	Concave	Bottom to mid
L	Level to moderate	Concave	Bottom to lower mid
M	Gentle to moderate	Even to convex	Lower mid to top
N	Level to very steep	Convex to concave	Bottom to top
MN	Gentle to moderate	Convex	Bottom to top
S	Very steep	All	Bottom to upper mid
Wo	Steep to very steep	All	Bottom to top
G	Steep to very steep	All	Bottom to top

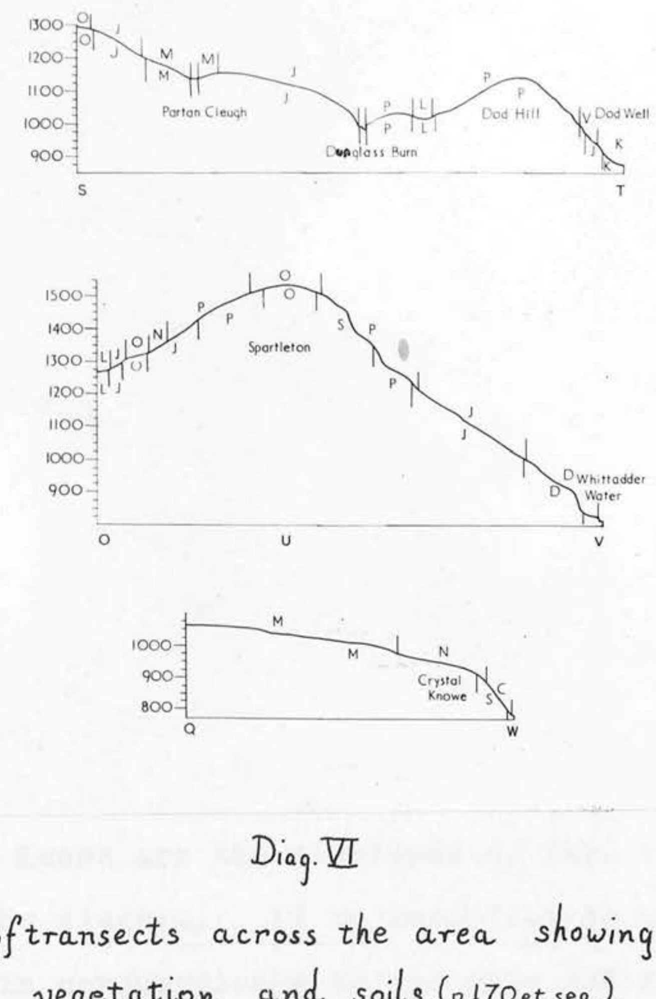


Diag. IV

Profile diagrams across the Lammermuirs showing topography, vegetation and soils. (p.170 et. seq.)



Diag V



Diag. VI

Profiles of transects across the area showing topography, vegetation and soils. (p.170 et seq.).

The effect of topography

For the purpose of this study topography has been divided into three features, gradient, land-form and position on the slope. The first two have been defined earlier and the last is considered in terms of four positions, top, upper mid slope, lower mid slope and base. The relations of the soils and vegetation with these are summarised in Tables 34 and 35,(pp 167-8) respectively. Diagrams IV, V and VI p.169 illustrate the points made in this section. They are transects across the area, shown as hill profiles, with the vegetation boundaries above the line and the soil boundaries below it. The vertical scale is four times the horizontal scale, exaggerating the relief. The transect sometimes crosses a slope at an angle to its steepest direction making it appear more gentle than it is. In some places, as at GH, diagram IV, the line crosses a series of rigs at right angles and the apparent tops of the low hills like Saddle Rig and Birny Knowe are the midslopes of long rigs running through the diagram. It is essential to use the diagrams in conjunction with the maps and not alone.

On the soils, topography exerts its influence mostly by erosion and drainage. Steep slopes, convex landform and high position favour erosion of the soil material and free drainage while the opposite condition, low gradient, concave form and low position favour accumulation of material from above and a high water table. The first type of topography bears shallow, less mature and dry soils while those of the second type are deeper, more greatly weathered and usually gleyed. The varying topography of the hill slopes provides conditions for a sequence of different soil types to develop.

From Table 34 it is clear that each soil type arises on sites with a particular combination of topographic features. Each feature may vary by itself but the combination of all three produces similar conditions, especially of drainage, in each site occupied by one soil type. For example, the soil drainage is the same in the mid position of a moderate to steep concave slope as it is on a gently rounded convex hilltop, both being sites often occupied by soil type J. Types S, T and Z, the screes, are always found on the steepest slopes such as those of Spartleton and the Bell Wood (Ref. 67/63), of the Hare and Holly Craigs (Ref. 65/72) and of the narrow valley sides bordering the Back Burn (Ref. 71/66). Type O occurs at the base or the top of hills where the slope is level to gentle and the landform concave or convex. Both types of site are found at Clints Dod (Ref. 62/68) shown on transect BI, diagram IV, and Spartleton shown on transect OV, diagram VI. Type C appears on the upper mid parts of moderate to steep slopes mostly along the Lammermuir Escarpment while type D is found on the somewhat less steep and often more concave sites a little lower down. Transects FG and GH, diagram IV, show some typical sites. Types K and L are associated with the lower parts of gentle concave slopes with K occurring in the slightly steeper and higher places as in transects AF, diagram IV, and QR, diagram V. Type M is associated with similar topographic conditions to type J (compare transect CD, diagram IV, p.169. with transect PR, diagram V), but occurs only in the central region between the Monynut and Bothwell waters and the west bank of the Eye water where the soil is derived from heavy textured glacial till.

Few hills have that uniformity of topography which would provide a habitat for one soil type only. Friardykes Dod (Ref. 66/69) is almost wholly covered by type M while String Hill (Ref. 70/65 and transect RS, diagram V p.169.) has type P on most of its western face. Both are small hills and both bear other soils in small patches, the former of J, K and L along the base, and the latter of type J at the summit. Hill sides are usually complex in form and bear a sequence of soil types corresponding to the changing topography. On areas of high relief where steepsided narrow valleys cut into the high hill masses as shown in transects GH, diagram IV, and DK, FM and RS, diagram V, the sequence from top to bottom runs O J P C or D. This is the commonest sequence on the west side of Spartleton Ridge and the northern part of Monynut Ridge. In some places the map and the transects show type P occurring above type J. This happens when the summit is narrow, steep and well drained as at Watch Law (Ref. 66/70) where the hill crest slopes steeply to the Lammermuir Edge while the mid slopes bearing type J run gently down to the Mossy and Tay Burns. Although the flat top of Spartleton is capped by peat, type O, the upper slopes, which are steep, have soil P and below this the long rigs reaching to the Whiteadder and Bothwell waters have soil type J (transect OV, diagram VI). Wherever soil type O runs straight into type P on the map there is in the field a narrow band of type J between them, but too narrow to be shown.

On the north central region the gentler concave slopes have a sequence of O J K L on Clints Dod and Wool Hill (Ref. 64/67) and of J P J K L O from Hall's Edge to Rammer Moss (Ref. 64/71). The absence of steep slopes makes for poor drainage and excludes types C and D, while the wide valleys allow large areas to develop soils K and L. The sequences usually end in a stream channel but in very wide level basins over 1,100 ft. deep peat is formed at the lowest levels (transect DF, diagram IV).

Type K, a poorly drained soil, is sometimes found nearer to the drainage channel than type L, a very poorly drained soil. This is most marked between Eachil Rig and Cracking Shaw Rig (Ref. 64/68). The streams of these small but wide and shallow valleys, when they overflow their banks, deposit most of their loads close to their normal margins so that these areas are often slightly higher than the parts farther away. In this area, close to the stream, water drains easily away into it while nearer the valley side the water which the land continuously receives from the hill slopes, percolates slowly through the soil. Thus the order of the sequence is reversed and the better drained soil comes after the less well drained. This is a common feature of mixed bottomland in the larger valleys where the stream is often contained by high banks of gravel and sand bearing bent-fescue grassland which slope gently away to soils of finer materials bearing mixed grassland with Nardus or rushes.

On the longer slopes of Lammermuir Edge the sequence runs J or P, C, D, K and L (see transects BI and CJ, diagram IV, and DK, EL and FM, diagram V). In very steep places types S, T and Z may take the place of types C and D.

The sequence M, K, L, is found in the part of the central region occupied by the Middle Ridge and the west side of the upper Eye valley.

In undulating slopes the soil sequence may repeat itself over an area. The sequence P, D, P, D, ... is not uncommon but the pattern is usually too small to be shown on the map. At the head of the Craig Burn (Ref. 67/67) the soil is mostly of type K with small knolls of type M recurring in it. At Rough Cleugh Burn (Ref. 71/64) soil type K predominates but type C or D covers many small knolls and a type approaching L appears in the depressions.

From this it is possible to deduce the sequence of soil types on an ideal slope which was long and of sigmoid form, the upper part convex and the lower concave. On the top the gently rounded surface is covered by peat, type O, which, as the slope dips gently away, gives place to type J. Further steepening leads to the appearance of type P followed by type C. At this point an increase in gradient would allow scree or colluvial soils, types S, T and Z to occur. The change to a concave form and decrease in gradient brings in type D which is followed by type K. At the base of the slope, on nearly level ground, type L is the characteristic soil. Normally the sequence O, J, P, C, D, K, L ends in a stream channel, but where the valley is wide and the stream small it is possible for peat to develop in the lowest parts, but only at elevations over 1,100 ft. This is a typical hydrologic sequence such as has been described earlier and illustrated in diagram II, p.76.

Soil type M falls outside this, for its occurrence depends on the presence of a parent material derived from heavy textured glacial till on convex slopes of low relief, which in this area are only capable of producing the sequence M, K, L.

The ideal slope is not found on the area, the nearest approach to it being some of the longer hill-sides of the Lammermuir Edge. On most slopes, because of lack of length or a far from ideal form, some of the members of the sequence are absent. Nevertheless the order of their appearance is almost always maintained.

It is apparent that topography is an important factor in determining the distribution of the soil types and within the area surveyed, probably the most important one.

The effect on the vegetation is as striking as that on the soils. Each type has a preference for a usually limited set of topographic features (see Table 35, p168), and its distribution seems to be correlated with that of suitable sites. Type P, the dry Calluna heath with few subsidiary species, is confined to the upper part of the region of high relief and is rarely found on land of concave form. It is most frequent in the southern parts of the Spartleton and Monynut p169

ridges (transects GH, diagram IV, and RS, diagram V). On the other hand, Juncus communeta, type L, is confined to hollows and basal slopes and is most frequently found in areas of low relief and concave form adjacent to the drainage channels especially in those tributaries of the Bothwell Water, the West Burn, the Mossy Burn and the Tay Burn.

Some types have a wide range. Bent-fescue grassland, type C, is to be found in a variety of positions, landforms and gradients. This is a most variable community and generally the lower positions are occupied by the facies including many species of damp areas while the upper positions are occupied by short dry turf with herbs characteristic of dry places. Nardus grassland also occupies a range of habitats. Nardus stricta is a constituent of every vegetation type and rises to dominance most often in places similar to those occupied by types C, J, K and M. Enclaves of it are frequent in type J, usually in gentle depressions or places where the gradient levels out slightly. In type K, Juncus articulatus, Nardus often forms the major part of a lower layer of plants, and becomes dominant on low knolls. It is agreed now that the spread of Nardus is due to bad management, of grazing or burning, on poor soils (Fenton 1937, 1947a, King 1955).

Recognisable and orderly sequences of the various types can be found on every hill side. In areas of high relief the sequence most often runs, from top to bottom O, J, P, D, sometimes with K or L at the base. Along the Lammermuir Edge J, C, D and P, C, D are frequent. At Hall's Edge type U takes the place of type J. In other areas its place is taken by type T. From Bothwell Hill to Birk Cleuch (Ref. 68/65) the order of the vegetation types is O, J, P, D, K and L. Clearly there is an ideal sequence running O, J, P, C, D, K, L. It may end in a stream channel or in type O where conditions are suitable.

In the central region around Crystal Well (Ref. 67/68) and Friardykes Dod (Ref. 66/69) the sequences start with <u>Molinia</u> grassland and run through <u>Nardus</u> dominated communities. Some typical sequences are M, N, K, L; M, N, C; M, MN, L. It is not clear whether MN is a transitional type because of topographic or biotic influences. It inhabits sites above, below and alongside type M. The sequence probably runs M or MN, N, K, L (transect PR, diagram V). Where the slope is very steep near the margin as at Crystal Knowe (transect QW, diagram VI), type C or D becomes part of the series.

The distribution of the vegetation types shows a correlation with topography but a causal relationship would be difficult to establish. It is shown below that the vegetation is correlated with the soil in a very marked way. It is probable that the topography has an indirect effect on vegetation, acting through the soil.

The relationship between soil types and plant communities

Laying the vegetation map beside the soil map it becomes immediately apparent that there is a strong relationship between the two. Not only are certain communities found associated with certain soil types but the boundaries of the units show a remarkably close coincidence. Diagrams IV, V and VI p169 illustrate the relationships between the soils, the vegetation types and the topography of the area. Table 36, p. 180, gives the soil types on which each community may be found and Table 37, p. 181, gives the plant communities borne by each soil. The greater part of the area occupied by each vegetation type occurs over a single soil type but each occurs in a minor way over one or several others, usually near a boundary line. There is some overlapping of related types within the OJP group and between K and L. Type C, bent-fescue grassland, has been shown to be a very variable community which develops on several soils.

The freely drained brown forest soil of low base status, soil type C, usually bears a short bent-fescue turf with Deschampsia flexuosa and low herbs, some-

Table 36. The vegetation of the various soil types.
p.179.

Vegetation types

Soil type	Main type	Minor types	Types occurring at the boundaries only	Probable errors in surveying
C	C, D, g	Wo, Wc	P, N	P
D	D, C, jg		N, J, T	
P	P	Wc	J, C, D, N	K, M
J	J, N	U, V, T, Wc	P, MN, M, O	M, O, C, D
O	O	J	J, N	N, P, M, K
M	M, MN	N, Wc	N, K	O, J, L, P
K	K, N	N, M, T, Wc	C, L, M	M, D, C
L	L	K, C		J, P, D
S	C, D, N, V, P	J, Dg		
T	C, D, Wo, V, P	N		
Z	S, Wo, Wb	D		
Cv	Cv			
M. bottom	All types			

Table 37. The soils associated with each vegetation type.

Vgn. type	Soil types: Main type	Minor types	Types occurring at the boundaries only	Probable errors in surveying
C	C, D	T, K, S		J, K, P
D	D	C, T, Z, S		P, K
CD	T			
j	D			
g	C, D			
P	P	J	D, C	
J	J	P	O, M, D	D
T	J	K	P, D	
U	J			
V	J, S			
O	O	J	M, P	
M	M	J	K	
MN	M	J	K	
N	J, M, K, S	C, D, P		O
K	K	L	M	
L	L	K		
Wo	C, D, Z, T			
Wb	Z, C			
Wc	M, J, C, K, P			

times with gorse or dwarf bracken. Nardus grassland and Calluna - Erica cinerea communities are also found. This is in agreement with previous work.

The slightly poorly drained brown forest soil, type D, usually bears an agrostis-fescue sward dominated by Bracken. Rarely a Nardus grassland takes its place. The map shows a correlation with type J, Calluna - Juncus squarrosus - Nardus but this may possibly be due to an error in surveying as the two have not been recorded together before.

Soil type P, the freely drained podzol, mostly carries Calluna heath with few other species, the main subsidiary constituents being Deschampsia flexuosa and Vaccinium myrtillus. The other plant communities recorded on this soil, bent-fescue grassland, Bracken, Nardus - Vaccinium myrtillus heath and Calluna - Juncus squarrosus - Nardus are all mentioned in the literature.

Soil type J, the podzol with a gleyed A_2 horizon, may bear vegetation type J, Calluna - J. squarrosus - Nardus, or type T, Calluna - Nardus, or type U, Calluna - Trichophorum caespitosum, or type N, Nardus grassland. Minor correlations with Calluna heath, type P, Eriophorum moor, type O, Molinia moor, type M, and Molinia - Nardus grassland, type MN, are present.

Peat over fifteen inches deep bears a community composed mainly of Calluna, Eriophorum vaginatum and

Sphagnum spp. When it is very dry due to cutting or drainage large amounts of Nardus stricta are often present. Pearsall (1950) states that Molinia - Trichophorum caespitosum may dominate on this soil in eastern districts of Britain but he may be referring to peat over a gleyed subsoil which is not the same as the peat treated here. Hughes (1949) finds in Wales that this type bears a Nardus - Juncus squarrosus community or Molinia and Erica tetralix. All the other workers found a similar relationship to that established here.

The podzolic gley soil, type M, carries either Molinia grassland, or Molinia - Nardus grassland, and more rarely Nardus grassland. The latter is usually borne at the margins where the slope steepens and the soil type changes to type C or type P. The map shows both Nardus - Juncus articulatus grassland, type K, and Calluna - Eriophorum vaginatum, type O, occurring on this soil and this may not be due to errors in surveying for Hughes (1949) records the former and Mitchell and Jarvis (1956) and Muir and Fraser (1939) a mixed heath intermediate between Calluna - Nardus and Calluna - E. vaginatum. Muir (1934) records a Calluna - Trichophorum caespitosum moor in Morayshire. All these are from the more distant places and writers on nearby land (Ballantyne 1953, Muir 1955, Ogg 1935) record a Molinia dominated community.

A _Nardus_ grassland, type N, or a _Juncus articulatus_ - _Nardus_ community is always borne by the poorly drained non-calcareous gley soil, type K, in the Lammermuirs, and all the other areas recorded. Similarly soil type L, the very poorly drained non-calcareous gley, bears a grassland dominated by _Juncus communis_ and no other community has been recorded growing upon it.

As colluvial soils are always on steep and sometimes inaccessible places they contain all the deciduous woodland remaining in the area. Type T, a colluvial soil of fine materials often difficult to distinguish from type C, the brown forest soil, may carry, where it is not bare, _bent-fescue_ grassland or oak-alder wood, or oak-birch or mixed birchwood. Type S, which is composed of small stones, bears _bent-fescue_ grassland, bracken or birchwood. Type Z is a bouldery scree and the few examples bear either a sparse cover of _Calluna_ and _Nardus_ or mixed oakwood.

The little valley floors, which have been mapped as mixed bottomland, are a mosaic of the soil types C, D, P, K and L mainly, with shingle banks, bare sand and muddy pools. The vegetation corresponds to the soils.

Each soil is closely associated with a single plant community or group of related communities. The climate of the area is fairly uniform throughout and ensures that the soils are leached,poor in bases and acid in character, and that the vegetation is heath, heath grassland or bog. The biotic factor comes mostly from sheep and their management which includes grazing by the animals and burning and draining by their owners. Its effect is to decide which of several possible types of vegetation will occupy an area; for instance, the absence of woodland from all but a few inaccessible places is due to it. The spread of Nardus stricta, a rough unpalatable grass of wide tolerance to soil conditions, has also been attributed to this factor (King 1955, Fenton 1937).

After climate and soil parent material the next most important soil forming factor is the moisture regime which varies according to the topography. Topography is therefore the principal factor differentiating the soils and through them controlling the distribution of the vegetation. Just as across the whole world climate, soil and vegetation form an ecological unit (Jacks 1932) so in a small region topography, soil and vegetation can form an ecological unit within the larger framework.

Summary and Conclusions of Section 1

The ecological work dealing with the soils and vegetation of regions similar to the eastern Lammermuir Hills has been studied and is reviewed in Chapter I.

The environment and history of the eastern Lammermuir Hills is described in Chapter II.

The soils present in the area have been classified into eight mature types and three skeletal types. They are described in Chapter III and their distributions on the land shown in a coloured map.

Sixteen plant communities have been recognised. These are described in Chapter IV and their spatial distribution shown on a coloured map.

While it is recognised that altitude, aspect and exposure together limit the distribution of cultivation on suitable land it is suggested that the apparent correlation between soil types and vegetation and altitude is due to topography. Only one vegetation type shows an association with a particular aspect and it is present in few places. Exposure cannot be separated from topography in a study of this type.

The soil types form a natural hydrologic sequence controlled by the topography on which they were formed. There is also a correlation between vegetation and topography which, it is suggested, is indirect.

There is a strong association between particular soil types and particular vegetation types.

Phot. 1.
The Lammermuir Edge near Common House.

Phot. 2.
Scree slopes at Crow cleuch.

Phot. 3.
The slopes of Wester Dod bear podzols and Calluna communities. Where cleuchs are grown over bent-fescue grassland and bracken dominate on immature soils.

Phot.4.
A bouldery scree at Bell Wood bears birches Pockets of fine coll-uvial material bear bracken.

Phot.5.
Scrub clings to the steep sides of narrow cleuches.

Phot.6.
Looking across the Bothwell Water to Crystal Rig and Friar-dykes Dod. Note the low relief of the central region.

Phot.7.
Molinia grassland at Crystal Rig.

Phot.8.
Bransly Hill. On the top a podzol bears <u>Calluna</u> and <u>Nardus</u>. On the lower slopes brown forest and gley soils bear bracken or <u>Nardus</u>.

Phot.9.
The gentle slopes of Watch Law have non-calcareous gleys bearing <u>Nardus</u>-<u>Juncus articulatus</u> grassland. The deserted croft of Boonslie stands on a dry knoll.

Phot.10.
In the Monynut Ridge the long dry slopes bearing heather are often bordered by bracken. Other light patches are due to muirburn.

Phot.11.
In the middle of a Calluna heath over a podzol a spring gives rise to a flush soil with rushes surrounded by bracken over a moist brown forest soil.

Phot.12.
The Snail Cleuch.
Bracken and brown forest soils border the stream.

Phot.13.
Sheep feed on the grass below withered bracken in wintertime. January

Phot.14.
The Monynut Water in winter. January

Phot.15.
Calluna-Eriophorum bog at Wester Dod.

SECTION 2

THE SURVEY OF SAMPLES OF THE SOILS AND THE VEGETATION

The first part of this work was devoted to establishing the main soil and vegetation types and their relationships. The next step was to discover the relationships which existed between the individual species and the soils. Inspection of the lists of species gives some impression of the range of soil types on which the plants may be found. The sample survey now to be described was devised to give quantitative data on the range of soils on which the various species grew and those soil types which provided the most congenial substrate for each.

Chapter VII

METHODS

The objections to a method of sampling in which only typical vegetation or typical soils are examined have been given in the review of the literature, to which may be added that this method ignores intermediate types and obscures trends or possible patterns of association between the two. It was decided to examine the sites at the corners and the centre of each 1 Km. grid square on the 1:25,000 scale Ordnance Survey map. Areas of high relief have a greater actual land surface for a unit of map surface than areas of low relief. To compensate partly for this two central sites were taken in any square with a rise in elevation of more than 300 ft. These were marked at one third and two thirds of the way along a north-south line in the middle of the square. Each site was listed under its shortened grid reference number, for example, 63/72 or 675/693.

The site was found with the aid of a map and compass. As near the selected spot as possible a quadrat was thrown to mark the location of the soil profile pit. The profile was examined and a short record made. Samples were taken and removed to Edinburgh for analysis. The quadrat was thrown twenty times in a circle of 15 ft. about the profile pit.

Archibald (1949) has shown that specific frequency gives an accurate representation of the composition of a vegetation if care is used in the choice of sampling unit. Too large a unit will give equal value to all the common or abundant species while too small a one will fail to find many plants and give others abnormally low values. The optimum size varies with the pattern of the community. For twenty throws in a <u>Nardus</u> grassland or <u>Eriophorum</u> bog it is 625 sq. cm. and in a <u>bent-fescue</u> grassland it is 25 sq. cm. To cope with the variation in the area a compromise was made with a quadrat of 100 sq. cm.

The soil sampleswere prepared by grinding and sieving in the normal way (Robinson 1949). The pH was measured with a Marconi portable glass electrode meter. The loss-on-ignition was also measured.

Eighty-six sites were sampled to yield collateral series of data on the soils and the plants. The figures relating to soils were treated to give the normal range for each type and an analysis of variance carried out to establish significant differences. To ascertain if any relationships existed between pH, loss on ignition and depth of the topsoils correlation ratios were calculated. The formula used was

$$\frac{C_1 + C_2 + C_3 \cdots C_9}{(A_1 + A_2 + A_3 \cdots A_9)(B_1 + B_2 + B_3 \cdots B_9)}$$

where $A = S(X^2) - \frac{(S(X))^2}{N}$

$B = S(Y^2) - \frac{(S(Y))^2}{N}$

$C = S(XY) - \frac{(S(X))(S(Y))}{N}$

This formula draws out any relationships existing between groups within the main series (D.N. Lawley, oral communication).

The average frequency of each species was calculated for every soil type. The analysis of variance cannot be used on statistics where absences are recorded, nor on finite figures such as percentages or figures out of a possible of twenty. In the event the differences could be seen clearly on inspection.

The ranges of pH, loss on ignition and soil depth were grouped and average frequencies calculated for each group to bring out relationships between the species and single factors.

The data made it possible to examine the following relationships:

Vegetation type with soil type
Vegetation type with topsoil pH
Vegetation type with loss on ignition
Vegetation type with topsoil depth
Numbers of species with soil type
Numbers of species with topsoil pH
Numbers of species with loss on ignition

Numbers of species with topsoil depth

Average frequency of a species with soil type

Average frequency of a species with topsoil pH

Average frequency of a species loss on ignition

Average frequency of a species with topsoil depth

The average frequencies for the individual species are given preceding an article discussing its soil relationships.

Tables 38, 39, 40 and 41 pp192-4 give the numbers of samples in the various groups. It will be seen that the samples are distributed unevenly over the soil types and the factor groups. This is unavoidable in a method of collecting random data, as the number of samples of a particular type which can be collected is proportional to the area occupied by that type.

Table 38. The number of samples collected on each soil type

Soil type	No. of samples
S	4
C	5
D	6
P	18
J	28
O	4
M	9
K	8
L	4

Table 39. The number of samples in each pH group

	Soil type								
pH group	S	C	D	P	J	O	M	K	L	T
3.1 - 3.5					1	2				3
3.6 - 4.0		1		15	15	2	4			37
4.1 - 4.5	2	1	3	3	10		5			24
4.6 - 5.0	1	2	2		2			2	1	10
5.1 - 5.5	1	1	1					4	2	9
5.6 - 6.0								2	1	3

Table 40. The number of samples in each loss-on-ignition group

Loss on ignition	Soil type									
	S	C	D	P	J	O	M	K	L	T
0 - 19%	1	2	4		1			8		16
20 - 39%	3	3	2	5	2				2	17
40 - 59%				2	1		1		1	5
60 - 79%				6	10		1			17
80 - 99%				5	14	4	6		1	30

Table 41. The number of samples in each topsoil-depth group

Soil depth	S	C	D	P	J	O	M	K	L	T
1 - 3 in.	1	1	4	2	2					10
4 - 6 in.	1	4	1	14	11		1	4		37
7 - 9 in.			1	2	13		3	4	2	24
10 - 12 in.	1				2		5		2	10
13 - 18 in.						1				1
over 19 in.						3				3

Chapter VIII

SOME CHARACTERS OF THE SOILS

The statistics collected during the survey were analysed to determine the real differences between the soil types. The means for four characters of each are given in Table 42, p.196 along with their standard deviations and standard errors. The normal distributions of three of these are illustrated in Diagram VII. p.198

The pH of the topsoils ranges from 3.21 to 5.73 in a continuous series of overlapping steps formed by the soils O, P, J, M, C, S, D, K and L, in that order. Diagram VII and the table of significance of the differences between means both show that it is possible to divide the whole range of soil types into three groups. The most acid group, ranging from pH 3.21 to pH 4.35, comprises the soils O, P, J and M, the middle, ranging from pH 4.13 to 5.19, includes types C, S and D, while the third and least acid group, ranging from pH 4.92 to pH 5.73 embraces soils K and L. The soils within each group show no significant differences from each other except for type O which differs from types J and M at the 5% level only. Overlapping of the groups is brought out by the fact that soil C is not significantly different from soil L and only differs from soil M and soil K at the 5% level. Both soil S and soil D differ from soil L at

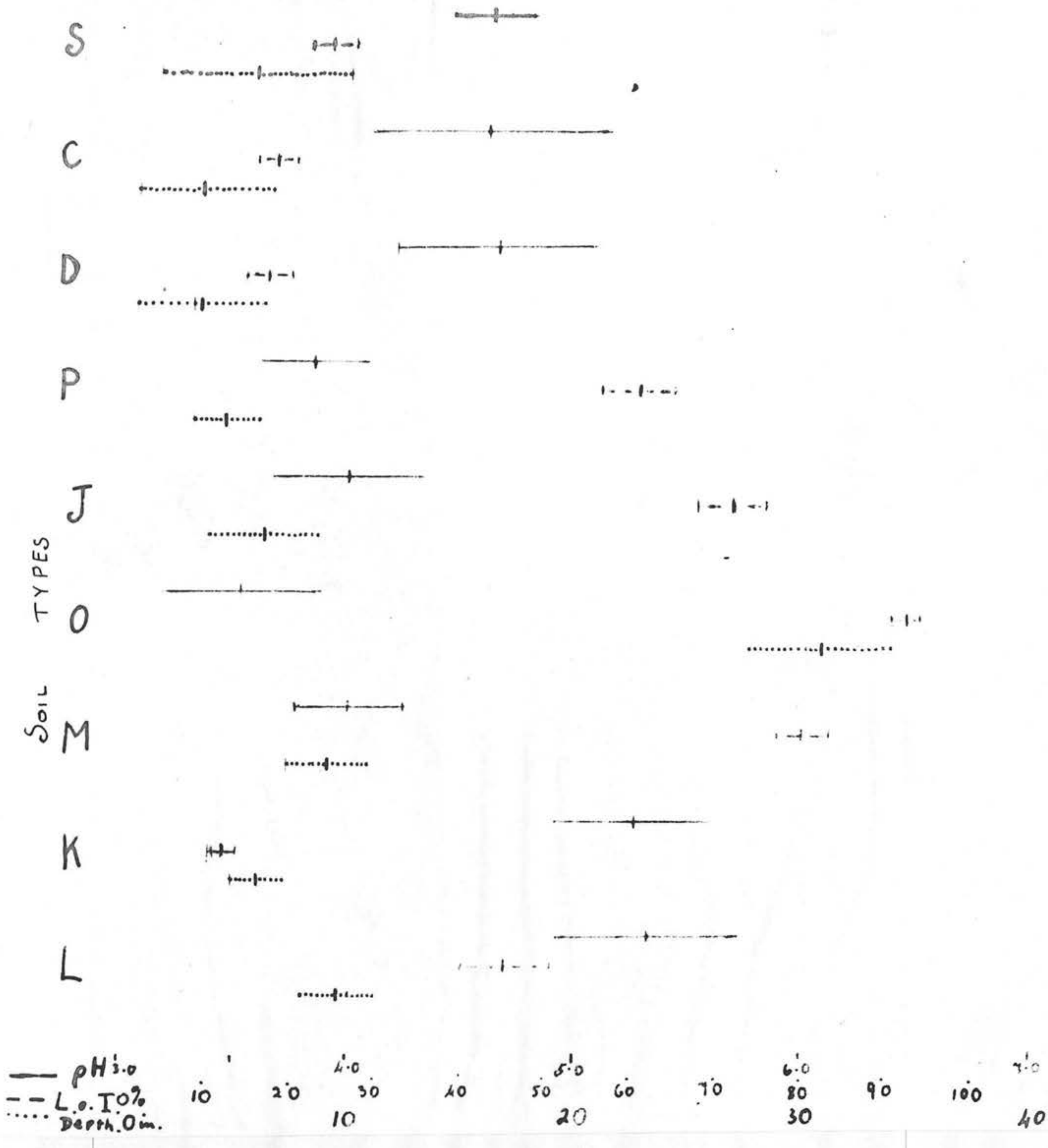
Table 42. The mean, standard deviation and standard error for pH, loss on ignition and depth of the topsoil and the pH of the subsoil for each soil type

Soil Type		Topsoil pH		L. o. I. %		Depth in.		Subsoil pH	
S	Mean	4.68	(4)	25.98	(4)	6.33	(3)	4.97	(3)
	S.D.	0.171		2.501		4.163		0.451	
	S.E.	0.085		1.251		2.403		0.260	
C	Mean	4.66	(5)	19.37	(5)	4.1	(5)	5.02	(5)
	S.D.	0.531		2.204		2.933		0.572	
	S.E.	0.238		0.986		1.311		0.256	
D	Mean	4.69	(6)	18.12	(6)	3.79	(6)	5.020	(6)
	S.D.	0.436		2.629		2.685		0.366	
	S.E.	0.073		1.073		0.448		0.149	
P	Mean	3.88	(18)	61.43	(18)	4.97	(18)	4.75	(18)
	S.D.	0.231		4.276		1.460		0.259	
	S.E.	0.054		1.008		0.349		0.061	
J	Mean	4.025	(28)	72.33	(28)	6.53	(28)	4.74	(28)
	S.D.	0.323		4.021		2.371		0.312	
	S.E.	0.061		0.760		0.448		0.059	
O	Mean	3.55	(4)	92.65	(4)	31.0	(4)	-	
	S.D.	0.342		1.673		3.162		-	
	S.E.	0.171		0.837		1.58		-	
M	Mean	4.02	(9)	80.44	(8)	9.28	(9)	4.93	(9)
	S.D.	0.244		3.031		1.787		0.573	
	S.E.	0.081		1.072		0.596		0.191	

Table 42 (contd.)

Soil Type		Topsoil pH		L. o. I. %		Depth in.		Subsoil pH	
K	Mean	5.27	(8)	12.55	(8)	6.13	(8)	5.94	(8)
	S.D.	0.351		1.595		1.134		0.758	
	S.E.	0.124		0.564		0.401		0.268	
L	Mean	5.33	(4)	45.41	(4)	9.63	(4)	6.05	
	S.D.	0.403		5.216		1.581		0.545	
	S.E.	0.202		2.608		0.791		0.272	

Figures in brackets denote the number of samples.



Diag. VII
The normal range of values of pH, loss on ignition and topsoil depth for each soil type. (Table 42)

Table 43. Analyses of variance of the factors in each soil type

	S.o.S.	D.F.	Mean square	Variance Ratio
1. Topsoil pH				
Between samples	20.80	8	2.60	20.312
Remainder	9.89	77	0.128	
Total	30.68	85		
2. Subsoil pH				
Between samples	14.59	7	2.0842	10.833
Remainder	14.05	73	0.1924	
Total	28.64	80		
3. Loss on Ignition				
Between samples	2340.9036	8	292.61	36.9245
Remainder	602.272	76	7.924	
Total	2943.1756	84		
4. Topsoil depth				
Between samples	52591.95	8	6573.99	22.868
Remainder	21647.22	76	287.46	
Total	74239.17	84		

These large ratios are significant at the 0.1% level and indicate real differences between the soil types.

Table 44. Significance of the difference between means

	L	K	M	O	J	P	D	C
S	5.0	1.0	0.1	1.0	0.1	0.1	NS	NS
C	NS	5.0	5.0	1.0	1.0	1.0	NS	
D	5.0	1.0	0.1	0.1	0.1	0.1		
P	0.1	0.1	NS	NS	NS			
J	0.1	0.1	NS	5.0				
O	1.0	0.1	5.0					
M	1.0	0.1						
K	NS							

Topsoil pH

	L	K	M	O	J	P	D	C
S	5.0	5.0	NS	-	NS	NS	NS	NS
C	5.0	5.0	NS	-	NS	NS	NS	
D	5.0	5.0	NS	-	NS	NS		
P	0.1	0.1	NS	-	NS			
J	0.1	0.1	NS	-				
O	-	-	-					
M	1.0	1.0						
K	NS							

Subsoil pH

Table 44 (contd.)

	L	K	M	O	J	P	D	C
S	NS	NS	NS	0.1	NS	NS	NS	NS
C	1.0	NS	NS	1.0	NS	NS	NS	
D	0.1	1.0	0.1	0.1	1.0	5.0		
P	0.1	5.0	0.1	0.1	1.0			
J	1.0	NS	0.1	0.1				
O	0.1	0.1	0.1					
M	NS	0.1				Topsoil depth		
K	1.0							

	L	K	M	O	J	P	D	C
S	0.1	0.1	0.1	0.1	0.1	0.1	1.0	1.0
C	0.1	0.1	0.1	0.1	0.1	0.1	NS	
D	0.1	0.1	0.1	0.1	0.1	0.1		
P	0.1	0.1	0.1	0.1	0.1			
J	0.1	0.1	0.1	0.1				
O	0.1	0.1	0.1					
M	0.1	0.1				Loss on Ignition		
K	0.1							

NS = Not significant

5.0 = Probably significant

1.0 = Significant

0.1 = Very significant

the 5% level. The first group contains all the podzolic soils, the second the brown forest soils and the third the two gleys. Soil S, the skeletal soil, falls in the middle group.

Considering these figures in the light of the scheme evolved by Pearsall (1952) for classifying vegetation types (see p.34) those limited to Class I soils (pH below 3.8) will be confined to soil O and parts of the area occupied by types P, J and possibly M. Vegetation limited to Class II soils (pH 3.8 to pH 4.8) may be found on soils S, M, C and D and parts of the areas occupied by types P and J. In this region only soils K and L can be occupied by plant communities preferring Class III soils (pH 5.0 to pH 6.0). There are no soils belonging to Class IV (pH 6.5 and over).

Using the classification devised by Small (1954) for separating species according to their soil pH requirements (see p.33) it is found that this factor should operate to confine the species to particular groups of soil types. Acidiphilous plants will be confined to soils O, P, J, M and Parts of the areas occupied by soils S, C and D. The acid tolerant plants of group (a) will be found on all soils but in the case of types K and L in some sites only. Group (b) will appear on all soils. Amphitolerant species will be found on all soils and for the purpose of this survey acid tolerant group (b) species will be included with them as it will be impossible to separate the two. Mesophilous species should be present only on soils K, L and parts of S, C and D. Alkatolerant species should appear on the same soils in the same way. No alkaliphilous species ought to be present on the area. In treating of the species recorded in the survey only four groups can be recognised, acidiphilous, acid tolerant, amphitolerant (including acid tolerant group (b)) and mesophilous (including alkatolerant) but in dealing with species for which data is available on this subject it should be possible to use the full classification.

In the subsoils the pH ranges given are all higher than the corresponding figures for topsoil. Table 44 showing the significance of the differences between the means for these figures shows that the heavy parent material represented by soils K and L has a higher pH than the lighter textured material. The low pH shown by soil M which is derived from heavy parent material is probably due to the presence of acid drainage water seeping down from the mor of the topsoil.

Two kinds of organic matter are found in the topsoils in this area, mor and moder. Mulls are found only in a very few moist woodland soils and were not recorded in the survey. A mor topsoil is characteristic of soils P, J, O and M and a moder of soils C, D and K. Types S and L may have a mor or moder topsoil. Although in a pedological classification it is usual to regard a moder topsoil with a low content of organic matter as a characteristic of all low calcareous gleys, the very poorly drained type sometimes, and in hill regions frequently, carries an overburden of peaty material of high organic matter content. Quite often several layers of peaty or silty material alternate with mixed mineral and organic layers. The pedologist uses as his criterion the lowest A horizon which is invariably a moder. From the point of view of plant growth and distribution the overburden cannot be ignored. Soil type L shows a wider variation in organic matter content than any other soil and a much deeper topsoil than type K.

The organic matter type does not conform strictly to the limits set by Pearsall (1952) in his classification. Mor is found here in Classes I, II and III instead of Class I only. Moder occurs in Classes II and III instead of II only and mull, a characteristic of Class III and IV, is absent. The classification is empirical and its limits should be seen as approximations rather than rigid definitions. Allowing for variation due to the nature of the region as well as the methods of sampling and analysis it can be seen that the trends shown by this survey tend to conform to Pearsall's classification.

In the podzolic group both the depth of mor and the percentage loss on ignition rise from the respective 3.5 - 6.5 ins. and 57.2 - 65.7% of type P through J and M to the 27.8 - 34.2 inches and 91 - 94.3% of soil O. The depth figures are closer to each other than the content figures but the differences are significant in both cases (Table 44).

In the moder soils the figures for depth are very variable except for soil K and the variability ensures that most of the differences are not significant. Types C, D and S include some shallow soils. The figures for percentage content of organic matter are all significantly different from each other except for types C and D. Type K is the least variable while types S and L show their heterogeneity in the figures, intermediate between the high values of the mor soils, above 60%, and the lower values of the moder soils, below 20%.

Table 45. The ratios for correlations between soil factors.

	Correlation ratio r.	Standard Error of r.
Topsoil pH and Loss on Ignition	0.006	0.10846
Topsoil pH and Soil Depth	0.1363	0.10644
Loss on Ignition and Soil Depth	0.001	0.10846

As none of the correlation ratios is greater than twice its standard error there can be no relationship between the values for these factors.

Chapter IX

THE ASSOCIATION BETWEEN THE PLANT COMMUNITIES AND THE SOILS

The association between plant communities and soil profile types

Table 46. Number of sites occupied by each soil - vegetation pair

Soils	Deciduous wood	A-f. grassland	Bracken	Calluna heath	Calluna mixed heath	Calluna - Trichophorum	Calluna - Eriophorum	Calluna - Nardus	Nardus	Molinia - Nardus	Molinia grassland	Juncus articulatus	Juncus communis	Total soils
C		2	2						1					5
D	1	2	3											6
P				11	4			2	1					18
J		1		1	12	2	1	2	4	1	4			28
O							4							4
M					3	1			1		4			9
K									3			4	1	8
L		1											3	4
Totals	1	6	5	12	19	3	5	4	10	1	8	4	4	82

The vegetation type and the soil type were noted at each site which was sampled. Table 46, above, gives the numbers of sites sampled on every soil-vegetation pair. A cursory inspection reveals the fact that the number of associations which can be formed between any member, such as a type of vegetation, and any other member, say a soil type, is limited.

As the distribution of soil types is dependent on geology and topography it follows that in most localities some soil types will cover much larger areas of ground than others and the numbers of samples collected from the former will be much greater than from the latter. In soil-vegetation relationships it has been shown that vegetation is the dependent member (Jenny 1941, Robinson 1949). A single vegetation type may occur on several soil types although most strongly associated with one. In a random method of sampling the number of each soil or vegetation type sampled is proportional to the area it covers. Thus it is possible to obtain a large number of samples of a vegetation type over a particular soil type on which it forms a small proportion of the vegetation and a similar or smaller number of sites on another soil type on which it forms a larger proportion of the vegetation. Nardus grassland was sampled four times on the podzol with gleyed A_2 horizon (soil type J) and three times on the poorly drained non-calcareous gley (soil type K), yet it forms 38% of the vegetation of the latter and only 14% of the former. The figures have therefore been converted into percentages for each soil type in order to show the proportions of each vegetation type which would occur if each soil type occupied areas of equal size (Table 47).

Table 47. The proportion of each soil type covered by each vegetation type

Soils	Deciduous wood	A-f. grassland	Bracken	Calluna heath	Calluna mixed heath	Calluna - Trichophorum	Calluna - Eriophorum	Calluna - Nardus	Nardus	Molinia - Nardus	Molinia grassland	Juncus articulatus	Juncus communis	Total soils
C		40	40						20					100
D	17	33	50											100
P				61.1	22.2			11.1	5.6					100
J		3.6		3.6	43.0	7.0	3.6	7.0	14.3	3.6	14.3			100
O							100							100
M					33	11.0			11		45			100
K									37.5			50	12.5	100
L		25											75	100
Totals	17	101.6	90	64.7	98.2	18.0	103.6	18.1	88.4	3.6	59.3	50	87.5	

Table 46 therefore gives the actual proportions of each vegetation type, and each soil type, present on the area, while Table 47 gives the proportions of each vegetation type in a way that allows of comparison between soil types as well as within them. Table 48, p210 which is derived from Table 47 shows the proportion of each vegetation type which would occur on each soil type if the soils all occupied equal areas. It facilitates comparisons within the columns by reducing the total figure for each plant community to a single standard - 100.

Table 48. The proportion of each vegetation type which would occur on each soil type if there were equal areas of soil types

Soils	Deciduous wood	A-f. grassland	Bracken	Calluna heath	Calluna mixed heath	Calluna - Trichophorum	Calluna - Eriophorum	Calluna - Nardus	Nardus	Molinia - Nardus	Molinia grassland	Juncus articulatus	Juncus communis
C		39.4	44.5						22.7				
D	100	32.5	55.5										
P				94.5	22.6			61.5	6.4				
J		3.5		5.5	43.7	39	3.2	38.5	16.0	100	24		
O							96.8						
M					33.7	61			12.5		76		
K									42.4			100	14.2
L		24.6											85.8
Totals	100	100	100	100	100	100	100	100	100	100	100	100	100

Deciduous woodland occurs only on the slightly poorly drained brown forest soil (type D), forming 17% of the vegetation. It had been noted in the earlier survey that its presence was usually associated with brown forest soils and a topography steep enough to restrict the access of grazing animals.

About three-quarters of the agrostis-fescue grassland would appear in the group of brown forest soils (Table 48) forming 40% of the vegetation of the freely drained series (type C) and 30% of the slightly poorly drained series (type D). It occupies a quarter of the area of the very poorly drained non-calcareous gley soil (type L) and only 3.6% of the podzol with gleyed A_2 horizon (type J).

Bracken, which may be regarded as an agrostis-fescue grassland dominated by the Bracken fern (Pteridium aquilinum), is wholly on the brown forest soils showing a slightly higher figure for the less well drained series.

Calluna heath, which contains the highest proportion of Calluna vulgaris and the lowest of other species of all the Calluna dominated communities, is almost wholly found on the podzol (type P) on which it forms 61% of the vegetation. A very small amount is present on the podzol with gleyed A_2 horizon.

Calluna mixed heath is found on three soil types, all of the podzolic group. It is mainly associated with soil type J, to a lesser extent with the podzolic gley (type M) and type P.

Calluna - Trichophorum caespitosum would have two-thirds of its area on soil type M forming 11% of its vegetation and one-third on soil type J of which it is 7% of the vegetation. It is therefore more frequently associated with type M than with type J although the map survey would suggest that its natural soil was type J.

Calluna - Eriophorum vaginatum forms the only vegetation of soil type O, the deep peat, and overlaps to the extent of some 3% into the vegetation of soil type J.

Calluna - Nardus stricta is confined to the two podzols, types P and J. It constitutes 11% of the vegetation of the former and 7% of the vegetation of the latter.

Nardus grassland occupies a wider range of soil types than any other plant community, being found on members of all three groups. The largest single amount would be found on the poorly drained non-calcareous gley (soil type K) of whose vegetation it is 38%. It constitutes one-fifth of the vegetation of the freely drained brown forest soil (type C). Some 35% of it would be distributed between three podzols, constituting 14% of the vegetation of soil type J, 11% of type M and half that figure on soil type P.

Nardus - *Molinia caerulea* was found only on soil type J where it forms a very small proportion of the vegetation.

Molinia caerulea grassland would have three-quarters of its area on the podzolic gley soil forming 45% of its vegetation. It constitutes about 15% of the plant cover of soil type J.

Nardus grassland characterised by abundance of *Juncus articulatus* forms half the vegetation of soil type K, the only soil on which it appears. *Juncus communis* is the dominant, however, in a grassland type which can be found on both series of non-calcareous gley soils. It forms three-quarters of the vegetation of the very poorly drained series (type L) and an eighth of that of soil type K.

The brown forest soils support an *agrostis-fescue* grassland sometimes dominated by Bracken or *Nardus stricta*. Places of more difficult access bear a deciduous woodland or scrub.

Soils belonging to the podzolic group are largely covered by plant communities in which *Calluna vulgaris*, the ling heather, is a dominant or characteristic plant. The best drained series, type P, is the characteristic soil of *Calluna* heath yet also carries some mixed heath and *Nardus* communities. Soil type J bears the widest range of vegetation cover of any, though this may be partly due to its occurring in the highest number of samples for any single soil. Most of the plant communities are Calluna associations related to mixed heath. Nardus and Molinia grasslands account for two-sevenths. Peat, soil type O, bears a single vegetation, Calluna - Eriophorum vaginatum, Cotton grass moor. Podzolic gley soils, type M, are covered by Molinia grassland mainly or mixed heath or sometimes by Nardus grassland.

Non-calcareous gley soils bear grassland mostly. In the poorly drained series it is a Nardus grassland, very frequently physiognomically dominated by Juncus articulatus, very occasionally by Juncus communis. The very poorly drained series is always a variant of bent-fescue grassland, in most cases dominated by Juncus communis.

These findings are substantially the same as those of the earlier survey by mapping. There are a number of minor discrepancies such as the fact that podzolic gley soils bear a larger proportion of mixed heath vegetation than was shown on the maps and the finding that Calluna - Trichophorum caespitosum is more frequently found on soil type M than, as formerly thought, on soil type K. The explanation of this latter is to be found in the uneven distribution of the soil types which tends to give the impression in a map survey that the vegetation is most commonly associated with the soil on which it is most frequently found. When the soil types have been balanced, as has been explained earlier, the real relationships become more apparent. Among other factors causing differences between the two accounts is the occurrence of two or more vegetation types in a mosaic of patches over a fairly uniform soil type. Mapping selects the most frequent plant community to represent the area but the statistical survey samples whatever occupies the selected site.

Bearing in mind that some reservations should be made in judging those soil-vegetation pairs for which low numbers of samples were obtained, the results reached are sufficiently positive to confirm the conclusions made in the original survey.

Vegetation type in relation to the acidity, the depth and the organic matter content of the topsoils (Table 49 p.216).

The *Calluna* dominated plant communities occupy those soils with the lowest pH figures and the largest content of organic matter. They are found exclusively and almost to the exclusion of all others on mor topsoils. The pH figures recorded for the group lie in the same narrow range below pH 4.0 and usually at pH 3.8. *Calluna* - *Trichophorum caespitosum* and *Calluna* - *Eriophorum vaginatum* return lower figures at pH 3.6 and pH 3.7 respectively. *Calluna* mixed

Table 49. The pH, percentage loss on ignition and depth in inches of the topsoils below each vegetation type

Deciduous woodland

	S	D	Average
pH	4.7 (1)	4.5 (1)	4.6 (2)
L.o.I.	26	16.5	21.25
Depth	3.0	1.5	2.5

Bent-fescue

	C	D	J	L	Average
pH	5.1 (2)	5.15 (2)	4.15 (1)	5.9 (1)	5.09 (6)
L.o.I.	17.38	20.35	88.4	21.0	30.81
Depth	6	5.5	4	9.0	6.0

Bracken

	C	D	Average
pH	4.1 (2)	4.55 (3)	4.39 (5)
L.o.I.	18.0	17.15	17.49
Depth	3.5	2.56	3.45

Calluna heath

	P	J	Average
pH	3.8 (11)	3.8 (1)	3.8 (12)
L.o.I.	63.6	70.0	64.16
Depth	4.59	5.0	4.63

Table 49 (contd.)

Calluna mixed heath

	P	J	M	Average
pH	3.85 (4)	3.83 (12)	4.03 (3)	3.89 (19)
L.o.I.	69.8	75.12	64.25 (2)	72.73 (18)
Depth	6.25	7.42	8.33 (3)	7.32 (19)

Calluna - Trichophorum

	J	M	Average
pH	3.65 (2)	3.6 (1)	3.63 (3)
L.o.I.	79.2	89.4	75.9
Depth	6.5	9.5	7.5

Calluna - Eriophorum

	J	O	Average
pH	4.3 (1)	3.55 (4)	3.7 (5)
L.o.I.	84.3	92.65	90.98
Depth	6.5	31	26.5

Calluna - Nardus

	P	J	Average
pH	4.13 (2)	4.35 (2)	4.24 (4)
L.o.I.	30.3	70.5	50.4
Depth	5.0	5.5	5.25

Table 49 (contd.)

Nardus grassland

	C	P	J	M	K	Average
pH	4.9(1)	4.3(1)	4.1 (4)	4.1(1)	5.03(3)	4.5 (10)
L.o.I.	26.2	66.0	42.95	82.8	13.05	38.6
Depth	3.5	4.0	4.63	6.0	4.6	4.65

Nardus - Molinia

	J
pH	4.4 (1)
L.o.I.	83.6
Depth	8.5

Molinia grassland

	J	M	Average
pH	4.43 (4)	4.1 (4)	4.26 (8)
L.o.I.	82.5	85.7	83.87
Depth	7.63	8.75	7.9

Juncus articulatus grassland

	K
pH	5.33 (4)
L.o.I.	13.28
Depth	6.75

Juncetum communis

	K	L	Average
pH	5.75 (1)	5.13 (3)	5.29 (4)
L.o.I.	8.1	53.54	42.18
Depth	7.5	9.63	9.25

heath has a higher pH on podzolic gley than on the other two soils on which it occurs. There is a trend from the shallower topsoils with relatively lower organic matter content of Calluna heath through the intermediate figures of mixed heath and Calluna - Trichophorum to the deep organic peats inhabited by Calluna - Eriophorum which reflects the increasing wetness of soil and decreasing angle of slope of the sites occupied by these types.

Calluna - Nardus stricta appears on the two podzols. In both cases it occupies sites with pH readings higher than average for the soil type. Nardus grassland also shows this feature along with an ability to inhabit a wide variety of conditions. It ranges over soils varying in pH from 3.8 to 5.4, in depth from 1 inch to 8.5 inches and in organic matter content from 10% to 83%.

Molinia grassland inhabits mor soils with a pH above 4.0, a depth between 7 and 8 inches and organic contents over 80%.

Agrostis-fescue grassland inhabits soils with a pH between 4 and 6. On brown forest soils the range lies around pH 5. The lower figure was obtained from a podzol where the species composition approaches Nardus grassland while the higher figure of 5.9 came from a site on a non-calcareous gley where the species composition approaches Juncetum communis in structure.

The organic matter is most often moder and forms 10 - 20% of the topsoil which is usually 4 - 6 inches deep. Bracken occupies a similar position, as it also occurs on brown forest soils. Deciduous woodland gives figures nearer to this type than any others, but it cannot be compared with them as its presence is due not so much to soil factors as to the nature of the terrain which on the one hand restricts grazing and on the other provides the conditions for the development of a brown forest soil.

The two rush grasslands occur on soils of high pH which are also all non-calcareous gleys. *Juncus articulatus* is found only on non-calcareous gleys and its figures for the soil factors are similar to those given earlier for that soil. *Juncus communis* shows more variable figures for the depth and organic content of the topsoil because of the presence occasionally of a mor composed of sedge or rush peat.

Although the figures are too few in some cases to be truly representative of every particular vegetation type on every particular soil type there are enough of them to allow of a broad treatment of the whole field. They do suggest that when classifying plant communities according to their preferences for various soil factors it is better not to draw hard and fast lines between the groups. Such a scheme as Pearsall (1952) has proposed should be based on criteria with some latitude in the boundaries, leaving the more detailed separations to personal judgment. Under this system Group I contains all the vegetation over soils of a pH lower than 4.0 and with a mor top horizon. This includes all the Calluna dominated communities and Molinia grassland. A case could undoubtedly be made, on grounds of its almost moderate acidity, for putting it in Group II but as it has in most cases a figure below pH 4.4 and is always on a mor topsoil of 80% organic matter it has more affinities with Group I. In Group II the soils have a pH of 4 to 5 and an organic matter of the moder type usually. This includes agrostis-fescue grassland and Bracken. The lowest figure in this group was obtained on a podzol with gleyed A_2 horizon where the species content approached that of Nardus grassland while the highest, pH 5.9, comes from a wet non-calcareous gley where the species content approaches Juncetum communis in structure. The relict of deciduous woodland included in the sample seems to have most affinities with this group. Group III vegetation is borne by soils with an acidity above pH 5.0 and usually moder topsoils but sometimes mor in the form of sedge or rush or grass peat. Juncus articulatus grassland and Juncus communis grassland belong here. Nardus grassland has a width of tolerance which allows it to span all three groups.

The podzolic soils and peat are contained in Group I, the brown forest soils and screes in Group II and the non-calcareous gleys in Group III. This system of classification also forms an altitudinal sequence and gives an indication of soil drainage. Group I embraces the vegetation and soils of the upper parts of the hills which in the Lammermuirs are usually gently rounded and thus of poor drainage. Group II contains those of the long steep slopes which promote good drainage while Group III contains those of the lower gentle slopes and valley bottoms where drainage is impeded.

This type of grouping is useful ecologically in that by measuring one or two factors an indication of the others can be obtained. It is however useless to expect an accurate forecast of all the environmental conditions surrounding a vegetation type by measuring a single factor, for instance, pH, as has been suggested (Pearsall 1952). In this area there is, as has been shown, no relationship between the soil factors measured, and within the soil types they overlap considerably.

Chapter X

THE SPECIES CONTENT OF THE VEGETATION IN RELATION TO THE SOILS

There are two standards on which this relationship may be considered. The first is the total number of species present on any soil type or factor group and the second is the average number of species on each group of sites within the soil type or factor-group. Both methods are given here, but in view of the finding that the larger the sample of a given vegetation the more species are found upon it (Archbold 1949) the latter is probably more accurate. In it the unbalance created by the widely varying number of samples for each group is evened out. In any case both methods lead to the same conclusions.

In species content the non-calcareous gleys and the brown forest soils are twice as varied as the podzolic group (Tables 50 and 51,p.224).The moist soils, K and D, carry larger numbers of flowering plants than either the dry soils, S and C, or the wet soil, L. This pattern is also suggested in the podzolic group where soils J and M show slightly higher figures than soil P, the dry podzol, and soil O, the wet peat.

Soil reaction is related to the base status, which has been shown to have a strong influence upon the richness or poverty of a flora (Evans 1944,

Table 50. The number of species of flowering plants in relation to the soil type

Soil type	Total no. of species per soil type	Soil type	Mean no. of species per site	Standard Deviation	Standard Error	n.
K	45	K	18.75	3.846	1.360	8
D	42	D	14.67	4.227	1.726	6
S	28	S	14.25	2.217	1.109	4
C	28	L	13.5	3.109	1.555	4
L	24	C	12.6	4.515	2.019	5
J	24	J	8.96	2.472	0.467	28
P	20	M	8.66	2.345	0.782	9
M	19	O	8.25	3.096	1.548	4
O	14	P	7.33	2.249	0.53	18

Table 51. Tests of the significance of the differences between means of numbers of flowering plants per site for each soil type

	L	K	M	O	J	P	D	C
S	NS	5.0	1.0	5.0	0.1	0.1	NS	NS
C	NS	5.0	NS	NS	NS	5.0	NS	
D	NS	NS	1.0	5.0	1.0	0.1		
P	1.0	0.1	NS	NS	5.0			
J	1.0	0.1	NS	NS				
O	NS	0.1	NS					
M	5.0	0.1						
K	5.0							

Table 52. The number of flowering plants present on each soil factor group

P.226.

pH group	Total no. fl. plants	Mean nos. fl. plants per site					
	All soils	S	CD	PJO	M	KL	All soils
3.1 - 3.5	16			8.3			8.3
3.6 - 4.0	27		9.0	7.8	9.3		8.0
4.1 - 4.5	45	14.5	11.0	9.3	8.0		9.8
4.6 - 5.0	43	15.0	16.3	10.0		14.3	14.3
5.1 - 5.5	50	13.0	16.5			19.0	17.8
5.6 - 6.0	27					17.7	17.7
L. o. I.							
0 - 19%	73	13.0	15.5	11.0		18.8	16.7
20 - 39	49	14.7	11.6	10.0		12.5	11.6
40 - 59	22			8.0	13.0	12.0	9.8
60 - 79	19			7.7	11.0		7.9
80 - 99	29			8.2	7.8	17.0	8.4
Depth							
1 - 3 in.	50	15.0	15.4	8.5			12.6
4 - 6	53	13.0	12.6	8.0	11.0	14.8	9.8
7 - 9	49		11.0	8.7	11.0	21.4	11.7
10 - 12	36	17.0		9.5	6.8	14.5	9.9
13 - 18	10			11.0			11.0
Over 19 in.	13			7.3			7.3

Holdgate 1955). Here the trend is what would be expected. The more acid the soil the fewer the species it supports (Table 52 and figs. 1 and 4).

The figures show that "mineral" soils are richer in flowering plants than "organic" soils. The relationship with soil depth is also a negative one (figs.2,3,5 and 6).

Figure 1

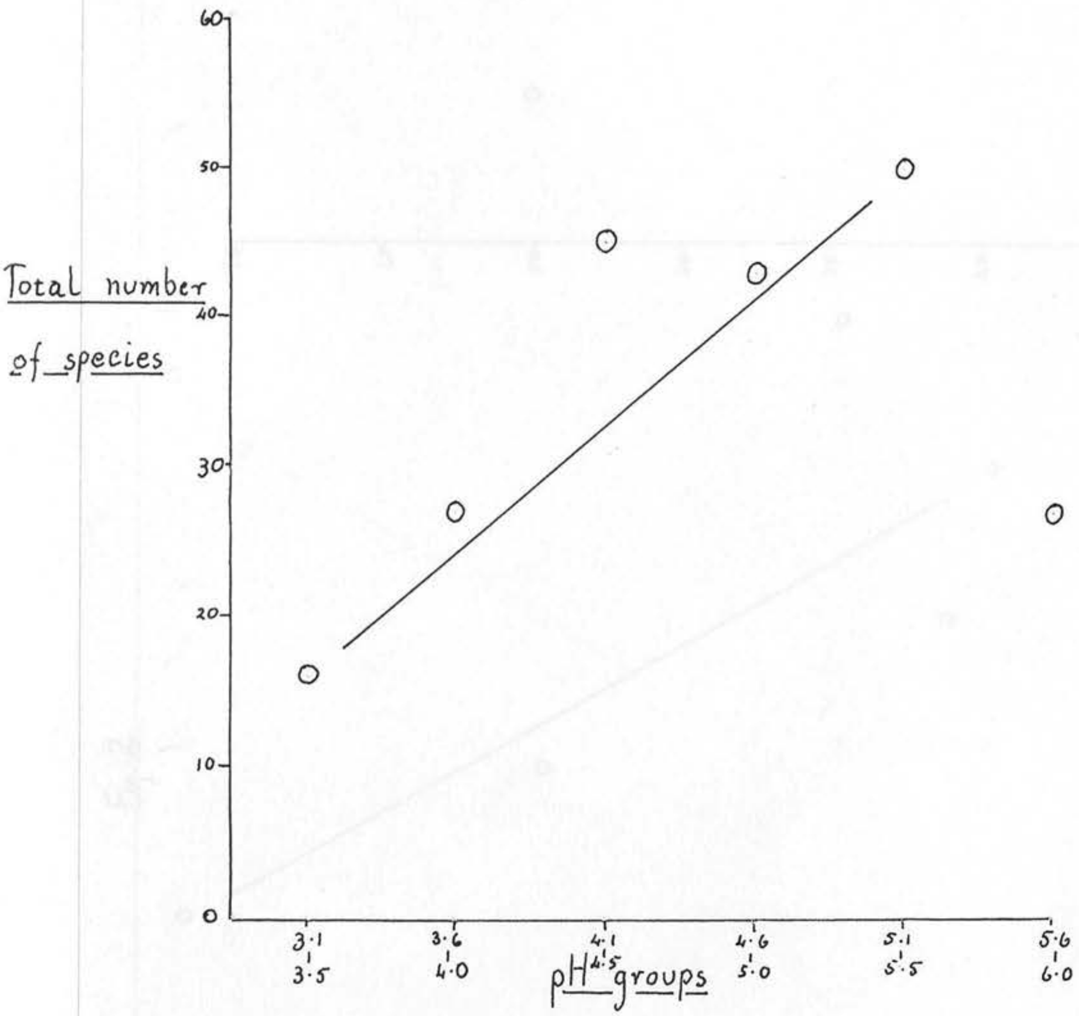


Fig. 2

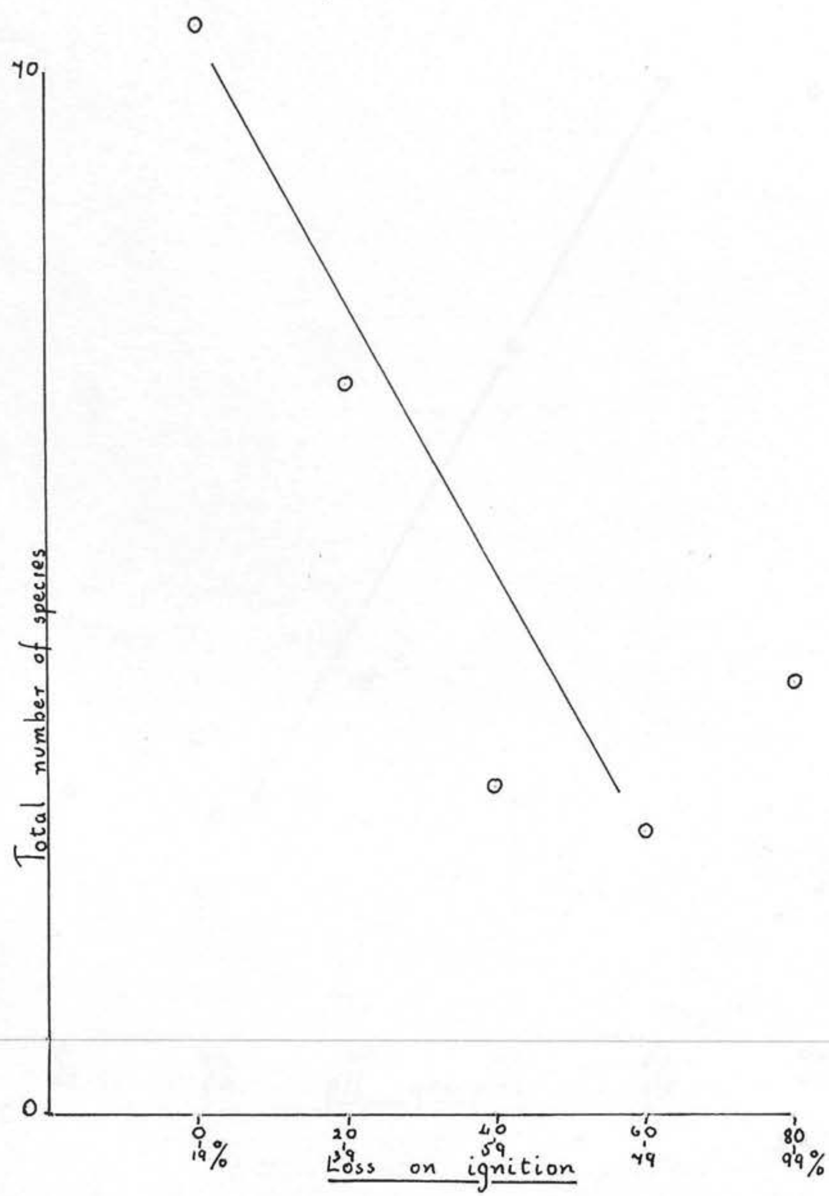
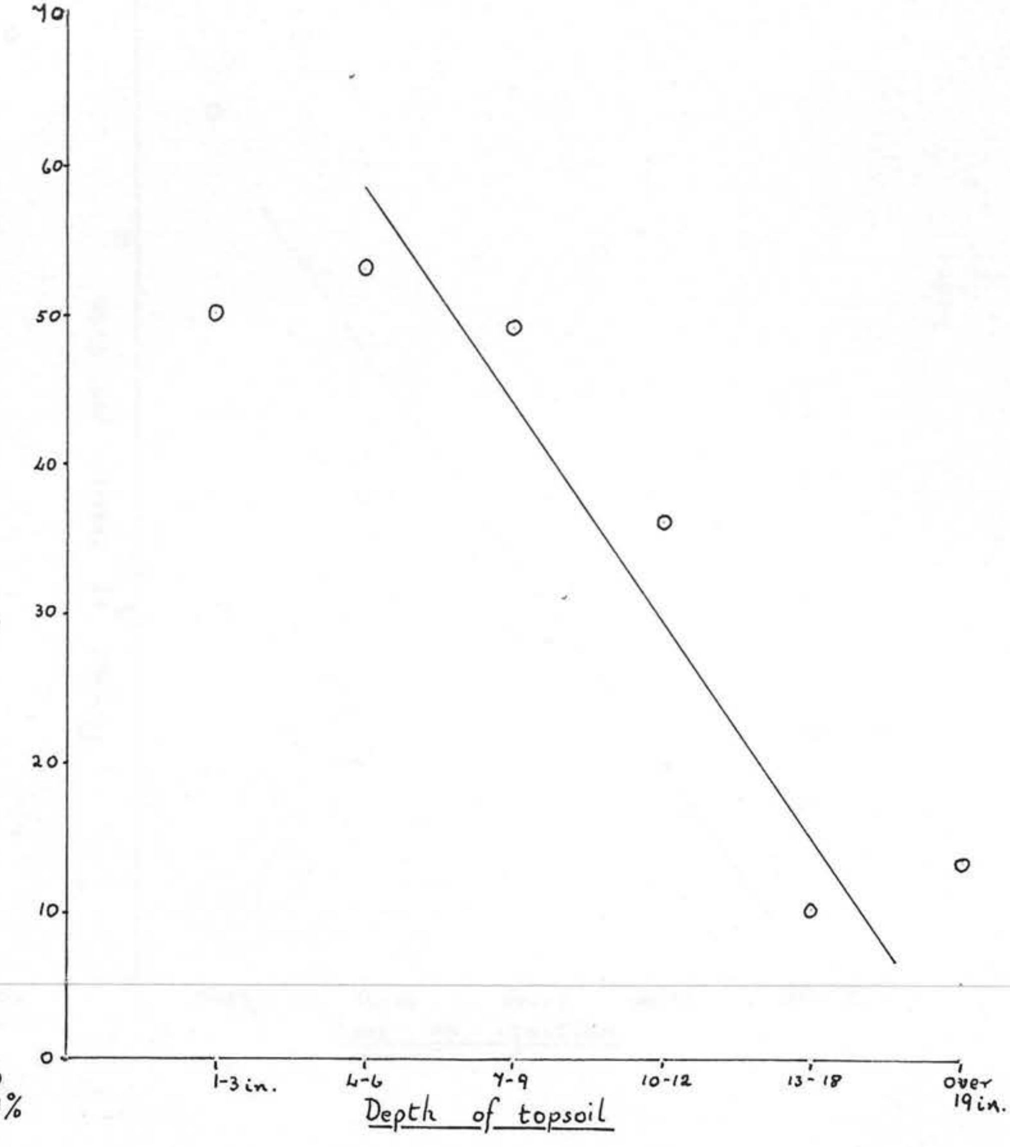

70
0
Total number of species
0-19%
20-39
40-59
60-79
80-99%
Loss on ignition

Fig. 3


70
60
50
40
30
20
10
0
1-3 in.
4-6
7-9
10-12
13-18
over 19 in.
Depth of topsoil

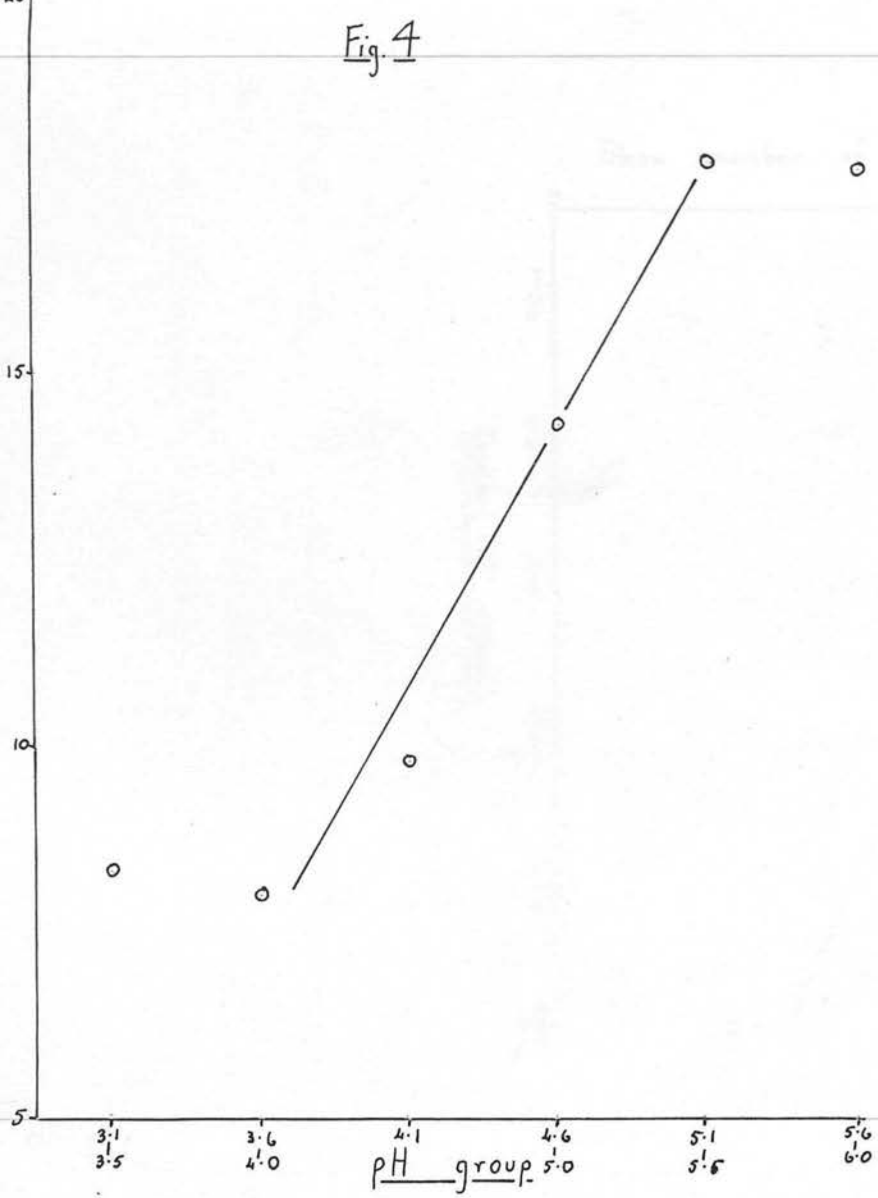


Fig. 4
20
15
10
5
3·1 – 3·5
3·6 – 4·0
4·1
4·6 – 5·0
5·1 – 5·6
5·6 – 6·0
pH group

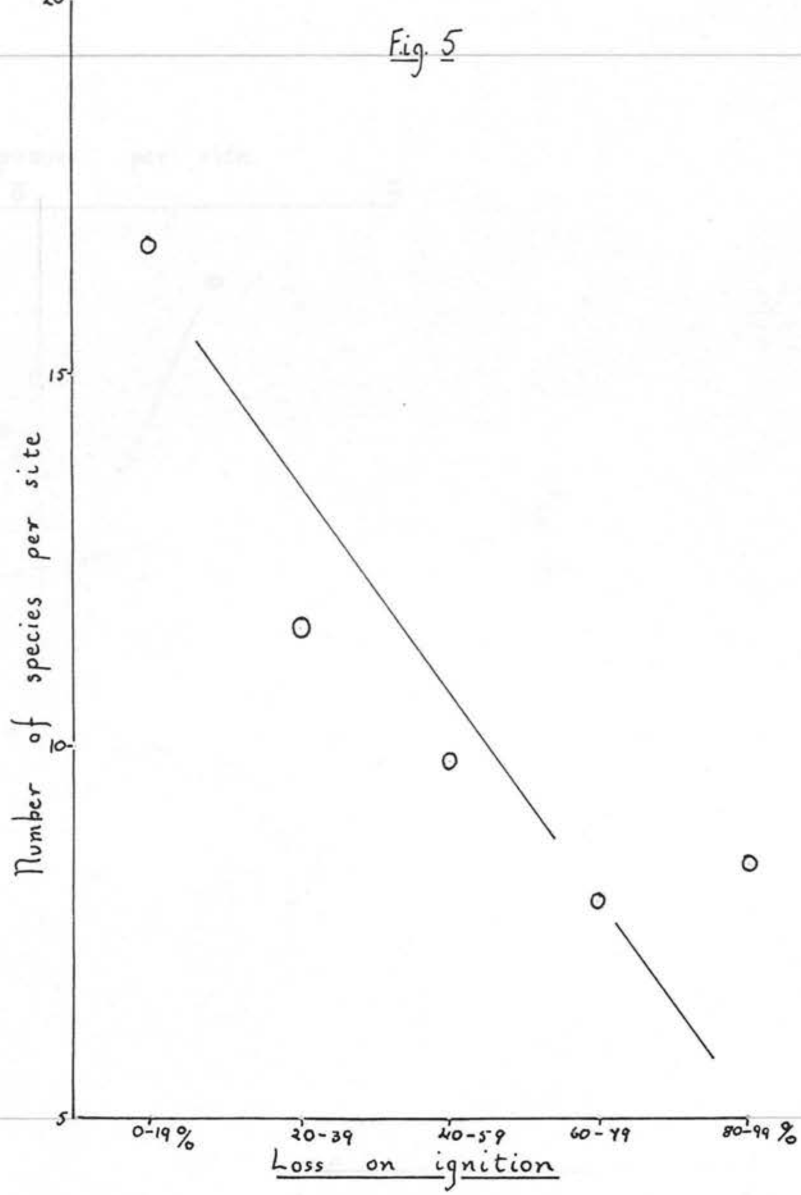
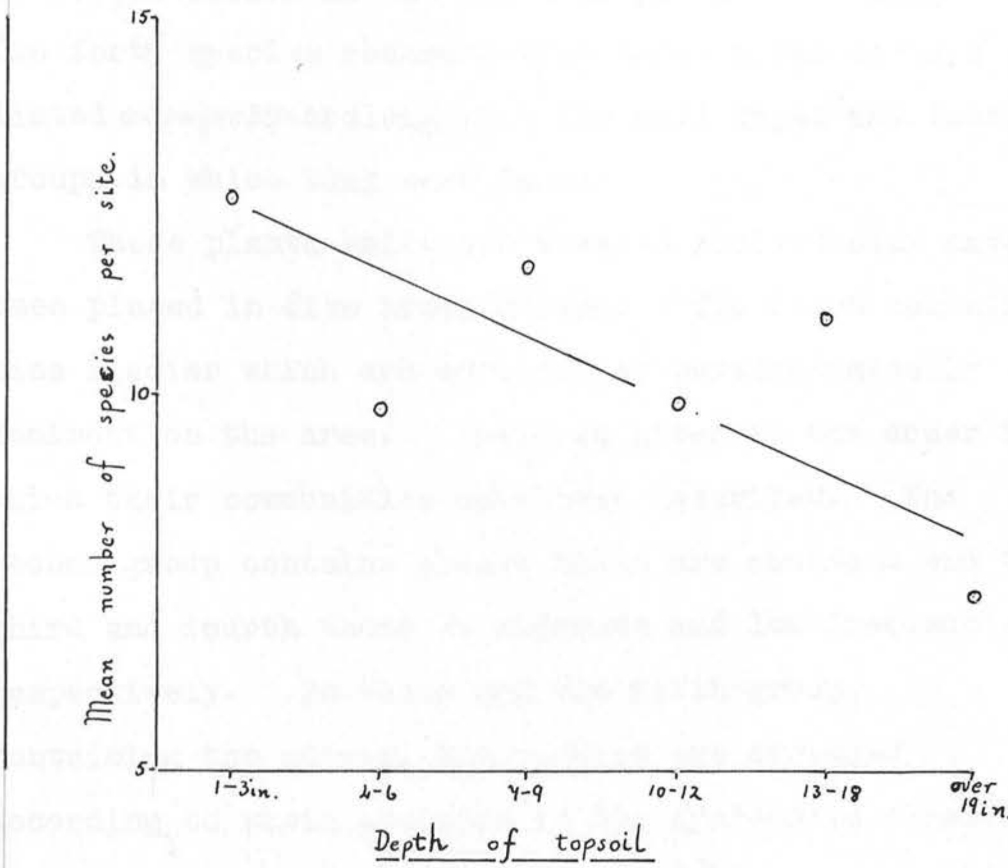


Fig. 5
20
15
10
5
Number of species per site
0-19%
20-39
40-59
60-79
80-99 %
Loss on ignition

Fig 6


Mean number of species per site.
15
10
5
1-3in.
4-6
7-9
10-12
13-18
over 19in.
Depth of topsoil

Chapter XI

THE RELATIONSHIPS BETWEEN INDIVIDUAL SPECIES AND THE SOILS

Each of the fifty-six species for which sufficient figures have been obtained is treated separately. Tables showing the average frequency are followed by a short discussion in the light of previous findings. The forty species recorded from three sites or less are listed on pages 339-42 along with the soil types and factor-groups in which they were found.

Those plants which are treated individually have been placed in five broad groups. The first contains nine species which are dominant or physiognomically dominant on the area. They are given in the order in which their communities have been described. The second group contains plants which are abundant and the third and fourth those of moderate and low frequencies respectively. In these and the fifth group, containing the mosses, the species are arranged according to their position in the systematic classification (Clapham et al 1952, Watson 1953).

As the numbers of sites on which species are found fall, so the accuracy of the findings becomes lower. The figures for each plant should be examined, bearing in mind the group to which it belongs.

Group 1: Dominant plants

Pteridium aquilinum

Soil type	Total Frequency	Average Frequency
D	56	9.3
C	37	7.4
S	27	6.8

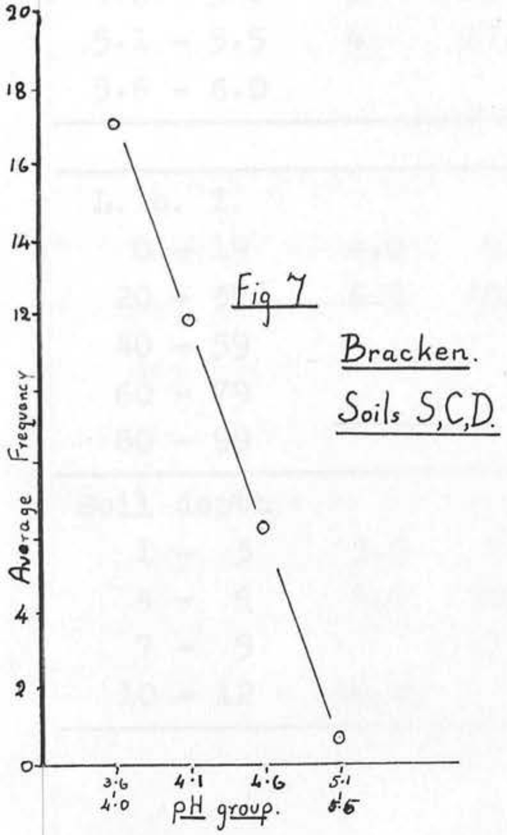
	S	C	D	CD	SCD	Total
pH group						
3.6 - 4.0		17.0		17.0	17.0	0.5
4.1 - 4.5	4.5	20.0	13.7	15.3	11.7	2.9
4.6 - 5.0	16.0	0	7.5	3.8	6.2	3.1
5.1 - 5.5	2.0	0	0	0	0.7	0.2
L. o. I.						
0 - 19	2.0	10.0	10.0	10.0	8.9	3.9
20 - 39	8.3	5.7	8.0	6.6	7.2	3.4
Soil depth						
1 - 3	16.0	17.0	10.0	8.0	12.2	7.3
4 - 6	2.0	5.0	16.0	7.2	6.4	1.0
7 - 9			0	0	0	0
10 - 12	5.0				5.0	0.5

It has been observed by Smith (1900), Farrow (1915), and Jeffreys (1917) and shown experimentally by Poel (1951) that Bracken avoids soils saturated with stagnant water but can tolerate submergence provided there is good aeration. Gimingham (1949) says it needs moist but not dry soils and Haines (1928b) has found that its ability to resist drought, varying with the situation in which it grows, in dry soils exceeds that of Calluna vulgaris. Crampton (1911) noted that it may spread into moorland podzols from less acid or more mineral nuclei in the immediate vicinity of surface stones, which suggests that the spore has a more critical tolerance of soil factors than the mature plant. R. Glentworth (oral communication 1950) has remarked on the ability of the rhizomes to break up the iron pan of podzols, thereby improving the drainage and leading to the breakdown of the layer of mor. Pearsall (1951) maintains that the fern is confined to brown forest soils of imperfect drainage. Where Bracken occurs in the Lammermuirs it is usually as the dominant plant. It is confined to the brown forest and scree soils in a series which suggests tolerance of excessive drainage but an association with moist conditions.

Bracken has been said to have a wide range of tolerance to soil reaction by Salisbury (1925) who put its limits at 3.6 and 7.6 with the greatest number of occurrences at pH 5.5. Jowett and Scurfield (1949a), using figures collected by Emett and Ashby (1934), found that within the range pH 4·8 to pH 6·1 Bracken preferred the higher values. Here it covers the whole range of pH values belonging to the soils it inhabits and shows a marked negative correlation with them (fig. 7).

It is found only on "mineral" soils, those with a loss on ignition value between 0 and 39%.

Both Tansley (1939) and Pearsall (1951) have commented on the need for a deep soil for full development of the fern. The latter gives 9 inches as the minimum depth in which it will grow. This is not borne out by the tables which give the highest average frequency in the 1 - 3 inch group.



Festuca ovina agg.

Soil type	Total Frequency	Average Frequency
K	108	13.5
D	67	11.7
C	44	8.8
M	75	8.3
L	31	7.8
J	166	5.9
S	23	5.8
P	99	5.5
O	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			1.3			1.3
3.6 - 4.0		0	4.0	10		4.6
4.1 - 4.5	8	4	8.6	6.8		7.4
4.6 - 5.0	3	15	11.0		7.0	10.6
5.1 - 5.5	4	17.5			13.5	13.3
5.6 - 6.0					12.3	12.3
L. o. I.						
0 - 19	4.0	9.5	2.0		13.5	10.7
20 - 39	6.3	10.8	8.9		9.0	9.0
40 - 59			3.3	9.0	1.2	5.0
60 - 79			4.3	16.0		5.0
80 - 99			5.3	8.4	7.0	6.0
Soil depth						
1 - 3	3.0	8.4	8.5			7.9
4 - 6	4.0	10.4	6.2	10	11.8	7.6
7 - 9		17.0	4.3	14	13.4	7.9
10 - 12	10.0		2.5	4.6	6.5	5.1

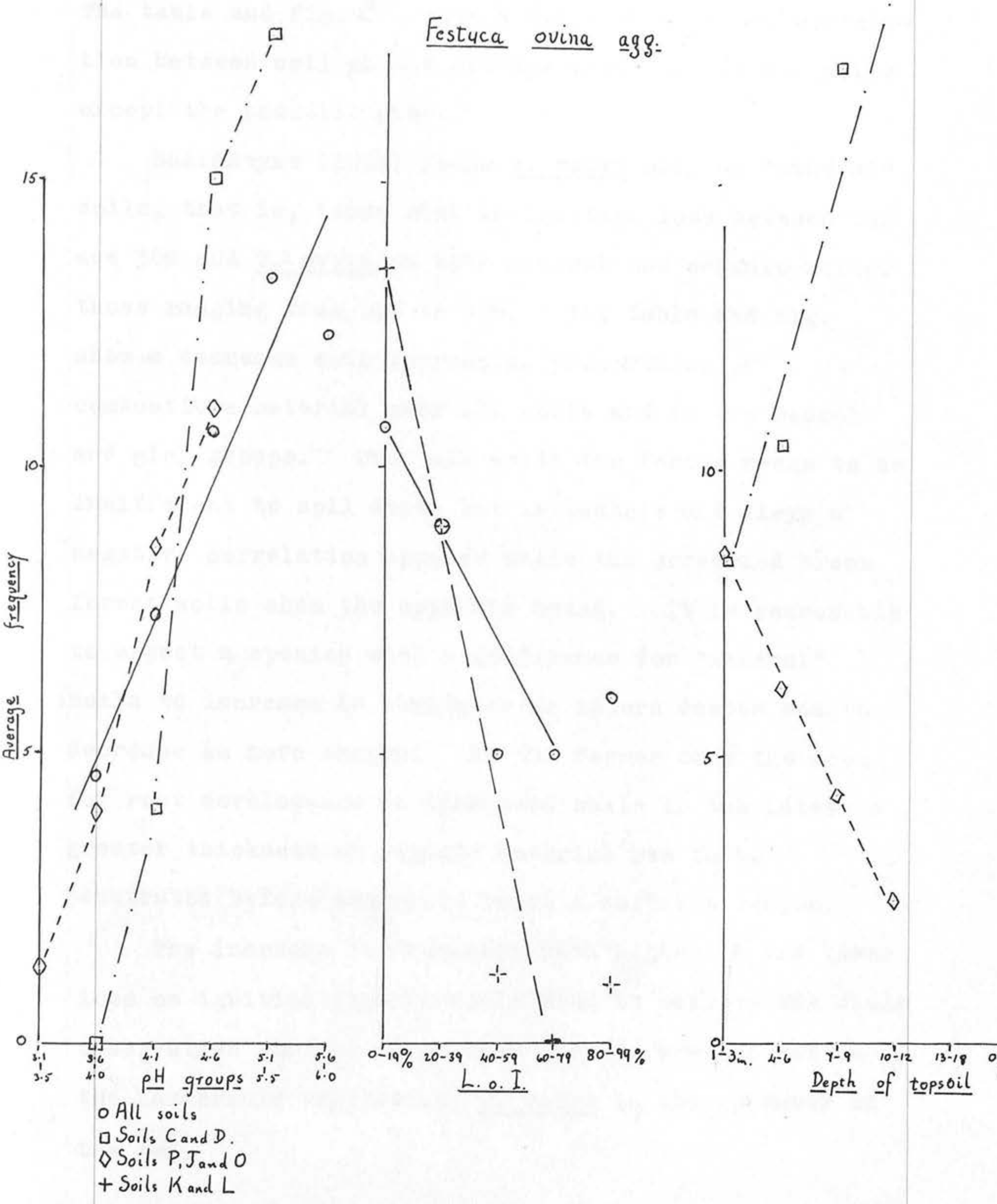
This, sheep's fescue, the co-dominant of bent-fescue grassland, is composed of two species, F. ovina sensu stricta and F. rubra L., which are difficult to distinguish between in quadrat analysis as has been already explained.

Earlier observers noted that F. ovina had a preference for the drier mineral soils (Smith 1904, Farrow 1917, Jeffreys 1917). Watt (1940) showed that while F. rubra was confined to transitional soils, F. ovina spanned the range from rendzina to podzol although decreasing in abundance as leaching progressed. Balme (1953) found F. ovina agg. indifferent to soil type in a similar range. Mitchell and Jarvis (1956) record both species from brown forest and locally in podzolic gleys, F. rubra in addition from non-calcareous gleys and F. ovina in addition from the podzols. The aggregate species is here found in appreciable average frequencies from every soil type except peat from which it is absent. The highest frequencies are recorded from the poorly drained gley and the moist brown forest soil followed by the dry brown forest, the podzolic gley and the gley type L. The two podzols and the scree come last but still in figures which are not very low.

The aggregate species has been recorded as having a wide range of tolerance to soil pH (Gimingham 1949) and a range from 5.0 to 7.8 (Atkins and Fenton 1930). There is agreement that while F. ovina decreases in

Fig. 8.

Festuca ovina agg.



frequency as the pH rises from 4.0 to 7.9, F. rubra increases between 4.0 and 7.9 (Olsen 1925, Fenton 1933, Heddle and Ogg 1933). This may explain why Balme (1953) found F. ovina agg. to be indifferent to soil pH. The table and fig. 8 show a striking positive correlation between soil pH and average frequency on all soils except the podzolic gley.

Ballantyne (1953) found F. rubra only on "mineral" soils, that is, those with an ignition loss between 10% and 36% and F. ovina on both mineral and organic soils, those ranging from 10% to 91%. The table and fig. show a decrease with increasing proportions of combustible material over all soils and in the podzol and gley groups. Over all soils the fescue seems to be indifferent to soil depth but in podzols and gleys a negative correlation appears while the scree and brown forest soils show the opposite trend. It is reasonable to expect a species with a preference for "mineral" soils to increase in abundance as moders deepen and to decrease as mors deepen. In the former case the room for root development is increased while in the latter a greater thickness of organic material has to be penetrated before the roots reach a suitable medium.

The increase in frequency with higher pH and lower loss on ignition figures would seem to confirm the field observation that although both species are present in the Lammermuir vegetation, F. rubra is the commoner of the two.

Agrostis tenuis

Soil type	Total Frequency	Average Frequency
D	77	12.8
L	37	9.3
K	72	9.0
S	32	8.0
C	14	2.8
M	12	1.3
J	27	1.0
P	15	0.8
O	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			0			0
3.6 - 4.0		0	0.3	1.8		0.4
4.1 - 4.5	8.5	8.3	0.3	1.0		3.7
4.6 - 5.0	4.0	9.5	0.5		6.3	6.2
5.1 - 5.5	11.0	10.0			10.2	10.2
5.6 - 6.0					9.7	9.7
L. o. I.						
0 - 19%	11.0	7.0	0		9.0	7.8
20 - 39	7.0	9.8	2.6		12.0	6.6
40 - 59			2.0	5.0	12.0	4.6
60 - 79			0.8	2.0		0.9
80 - 99			0.2	0.8	1.0	0.4
Soil depth						
1 - 3 in.	4.0	8.0	3.0			5.6
4 - 6	11.0	6.6	1.0	5.0	10.8	3.5
7 - 9		18.0	0.4	0.7	8.4	2.7
10 - 12	15.0			1.0	7.5	3.3

Common bent is often referred to in the literature along with Brown bent as Agrostis spp. Smith (1904) names it as the co-dominant with Festuca ovina on steep rocky land. Farrow (1917) noted that Agrostis spp. were the more prevalent of the two main species of bent-fescue grassland on the moist sites. Jeffreys (1917), on the other hand, found that it increased in abundance in grassland, at the expense of other species, as the soil was dried out by drainage but did not identify the soil type. Watt (1940) reports Agrostis spp. and Balme (1953) reports A. tenuis ranging from rendzina to podzol but reaching its highest density in the transitional or brown forest soils. Mitchell and Jarvis (1956) record A. tenuis in high frequencies or dominance over brown forest soils but not from podzols, peat or the very poorly drained gley (type L). Here it appears on all soils except peat but mainly on the moist brown forest, the two gley soils and the scree. It is fairly low on the dry brown forest soil and very low on podzols. The relatively high value obtained for screes, the driest of all, may well be due to the low level of competition and the low value in soil type C which is due to the factor of moisture allowing other species to compete more successfully in dry soils.

Ballantyne gives a range of pH for Agrostis spp. as 3.9 to 5.7. Olsen (1925) showed it increased with rising pH between 3.5 and 4.9 then decreased to 7.0.

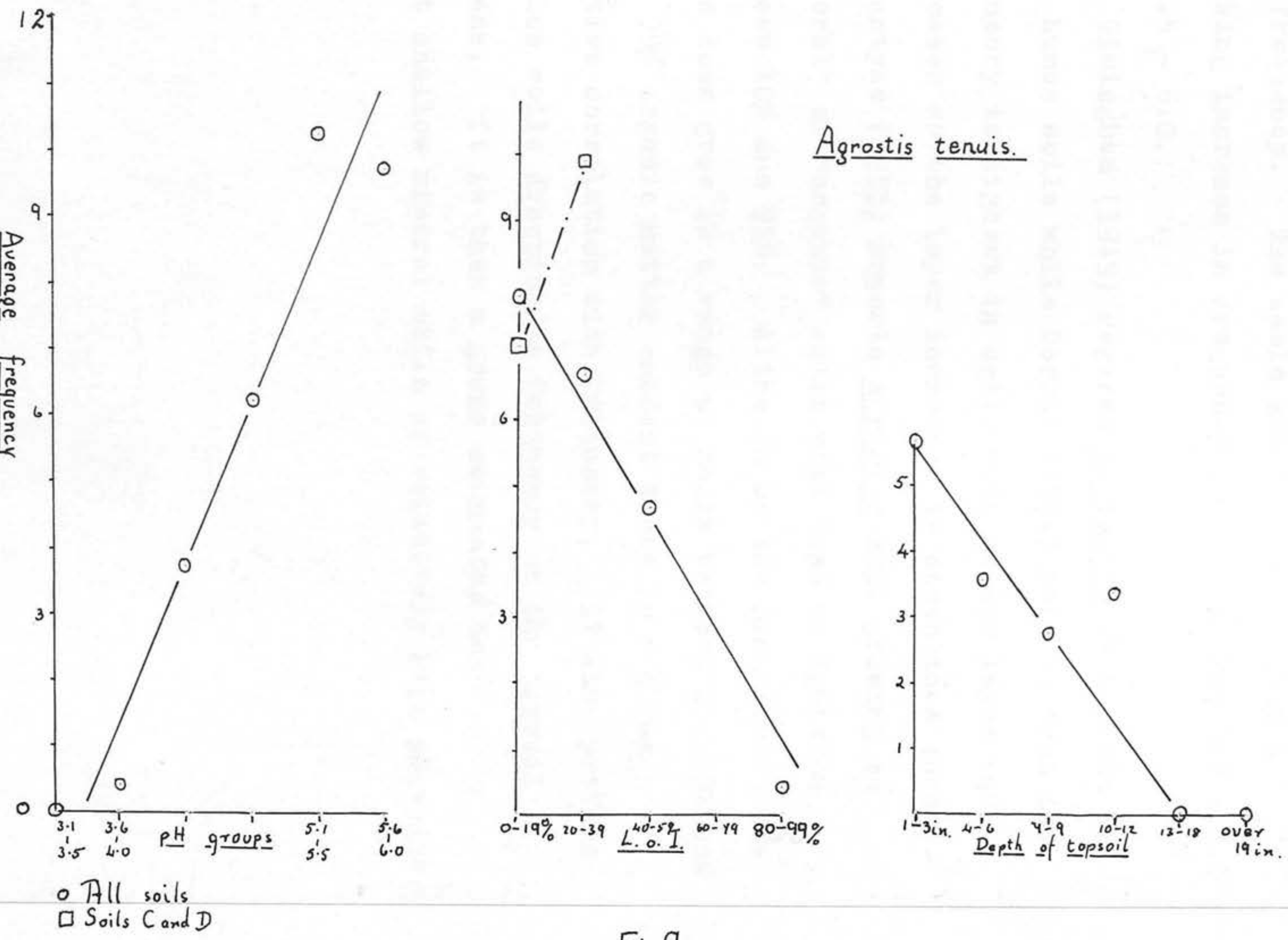

Agrostis tenuis.
Average frequency
12
9
6
3
0
3·1 3·5
3·6 4·0
pH groups
5·1 5·5
5·6 6·0
0-19%
20-39
40-59
60-79
80-99%
L. o. I.
5
4
3
2
1
1-3in.
4-6
7-9
10-12
13-18
over 19 in.
Depth of topsoil
o All soils
□ Soils C and D

Fig 9

On flushing acid pasture with water of a higher pH value Fenton (1933) found a decrease in density of Agrostis spp. while Heddle and Ogg (1933) found an increase in its frequency. The table and figure 9 show a striking increase in frequency on rising from 3.6 - 4.0 to 5.5 - 6.0.

Gimingham (1949) regards A. tenuis as a plant of thin humus soils while Gorham (1954) reports that its frequency is highest in soils with no mor layer and decreases as the layer increases in depth to 4 inches. Ballantyne (1953) reports Agrostis spp. growing on "mineral" or "organic" soils with loss on ignition between 10% and 91%. Although on the Lammermuirs the grass does grow in a range of soils between 0 - 19% and 80 - 99% organic matter content there is a clear negative correlation with frequency. It also prefers shallow soils dropping in frequency as the topsoil deepens. It is then a grass associated with moist shallow mineral soils of relatively high pH value.

Calluna vulgaris

Soil type	Total Frequency	Average Frequency
P	335	18.6
O	66	16.5
J	347	12.4
S	46	11.5
M	72	8.0
C	15	3.0
D	1	0.16
K	1	0.13
L	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			17.9			17.4
3.6 - 4.0		0	17.9	12		16.8
4.1 - 4.5	14.5	0.25	7.8	4.8		6.5
4.6 - 5.0	0	1.0	7.5		0.3	2.2
5.1 - 5.5	17.0	3.5			0	2.7
5.6 - 6.0					0	0
L. o. I.						
0 - 19	17.0	1.4	2.0		0.1	2.9
20 - 39	9.7	1.6	14.7		0	8.3
40 - 59			13.7	10.0	0	10.2
60 - 79			15.6	18.0		15.7
80 - 99			14.6	8.0	0	12.0
Soil depth						
1 - 3	0	0	15.0			6.1
4 - 6	17.0	3.0	15.7	2.0	0.2	12.2
7 - 9		0	12.9	12.7	0	9.8
10 - 12	12.0		19.5	6.4	0	8.3
13 - 18			15.0			15.0
over 19			17.0			17.0

Graebner (1901), Smith (1904), Farrow (1915) and Haines (1926) have all mentioned the almost exclusive association between Calluna and podzolic soils. In Ayrshire it is mostly found on podzols, peat and podzolic gleys (Mitchell and Jarvis 1957). In the eastern Lammermuirs, although it is found on every soil type except the very poorly drained non calcareous gley, it only reaches dominance or abundance on the podzolic series. The highest average frequencies are obtained from the podzol P and peat on which it is almost always the dominant and the next from the podzol J, the scree and the podzolic gley on which it is sometimes dominant, sometimes abundant and sometimes absent. The association with the driest and the wettest soils is notable for it seems to be the moist podzols which allow other species, especially Nardus and Molinia to displace Calluna. Haines (1928b) found Calluna to have a consistently greater ability to resist drought than any other of the heath plants he measured. This may give ling heather a competitive advantage in soils P and S and may in part explain its presence on the freely drained brown forest soil though it must be considered along with the fact that soil C is the most acid of the non-podzolic soils.

Records of soil pH values given by Olsen (1925), Atkins and Fenton (1930), Fraser (1933), Beijerinck (1940), Macleod (1948) and Klapp (1951) are in agreement with Small (1954) that ling belongs to the acid tolerant "a" group of plants. This means that it can tolerate a range from below pH 4.8 to between pH 5.5 and 7.0. Gimingham (1949) places the limits as pH 3.0 to pH 7.0 with a normal range from 3.4 to 5.9. The table and fig. 10 show that maximum frequencies occur between 3.1 and 4.0 and that from there to the 5.1 - 5.5 group there is a marked drop.

The association between "peaty" soils and the presence of <u>Calluna</u> mentioned by Adamson (1918) and Gimingham (1949) is brought out in the tables relating to soil type and to loss on ignition. Over all soils those groups with high figures contain the highest average frequencies yet within the podzolic groups there is no obvious association with ~~for~~ any particular group apart from an avoidance of the lowest. Over all soils the deeper may be preferred to shallower soils. Fig. 10 does show a probable positive correlation. Within the podzolic group there is again no obvious trend but it may be worth noting that the lowest figure, 12.9, comes from the 7 to 9 inch group which is composed largely of soil type J, the moist soil frequently colonised by <u>Nardus</u> or <u>Molinia</u>.

<u>Calluna</u>, the ling heather, is here associated with the acid peaty soils and some evidence is put forward in support of the findings of Rutter (1955) that it is most often associated with a fairly stable water table and that violent fluctuations favour <u>Molinia</u> at its expense.

Nardus stricta

Soil type	Total Frequency	Average Frequency
K	74	9.3
J	184	6.6
C	21	4.2
P	75	4.2
M	27	3.0
L	8	2.0
D	9	1.5
S	1	0.3
O	-	-

	S	CD	PJ	M	K	L	Total
pH group							
3.1 - 3.5			5.0				5.0
3.6 - 4.0		0	4.8	3.0			4.5
4.1 - 4.5	0	0	7.5	3.0			4.7
4.6 - 5.0	0	6.5	6.0		16.5		7.1
5.1 - 5.5	1.0	2.0			9.0		4.6
5.6 - 6.0					2.5	8.0	4.3
L. o. I.							
0 - 19	1.0	0.7	10.0		9.3		5.5
20 - 39	0	5.2	9.0			4.0	5.7
40 - 59			5.7	5.0		0	4.4
60 - 79			5.5	5.0			5.4
80 - 99			4.3	2.8		0	3.8
Soil depth							
1 - 3	0	0.6	6.5				2.9
4 - 6	1.0	4.2	5.7	15.0	14.0		6.4
7 - 9		6.0	4.5	2.3	4.5	8.0	4.4
10 - 12	0		9.5	1.0			2.4

An interesting feature of the Whitebent is the wide range of soils in which it can grow. Smith (1918) has described in soil-site or habitat terms all these represented in the table as possible substrates. Its appearance in abundance is controlled by the state of the soil moisture. The normal habitat in western Europe is given by Tansley (1939) and Klapp (1951) as an acid damp soil or a peaty or mineral gley with no iron pan but not a wet raw humus or peat over stagnant water, which accounts for the relatively high values in soils K and J and its absence from type O. Smith (1904) and Adamson (1918) have both noted that in heath and podzol soils (equivalent to types C, D, P and J) the grass becomes dominant in damp hollows or where the slopes flatten out. On steeper slopes with thin dry soils Nardus gives way to Deschampsia flexuosa and Festuca ovina (Jefferies 1917), a fact brought out in Table 55, p.362. It cannot stand submergence for long periods and is rarely found in very wet soils, thus a sharp boundary is often found between Nardus grassland and Juncus communeta (Jefferies 1917). The table shows a great fall in frequency between soil K and soil L, the two non-calcareous gleys whose boundaries are so often contiguous in the damp hollows of small tributary streams. The former frequently bears Nardus grassland and the latter always is dominated by Juncus communis. Jeffreys said that White bent gives way in such

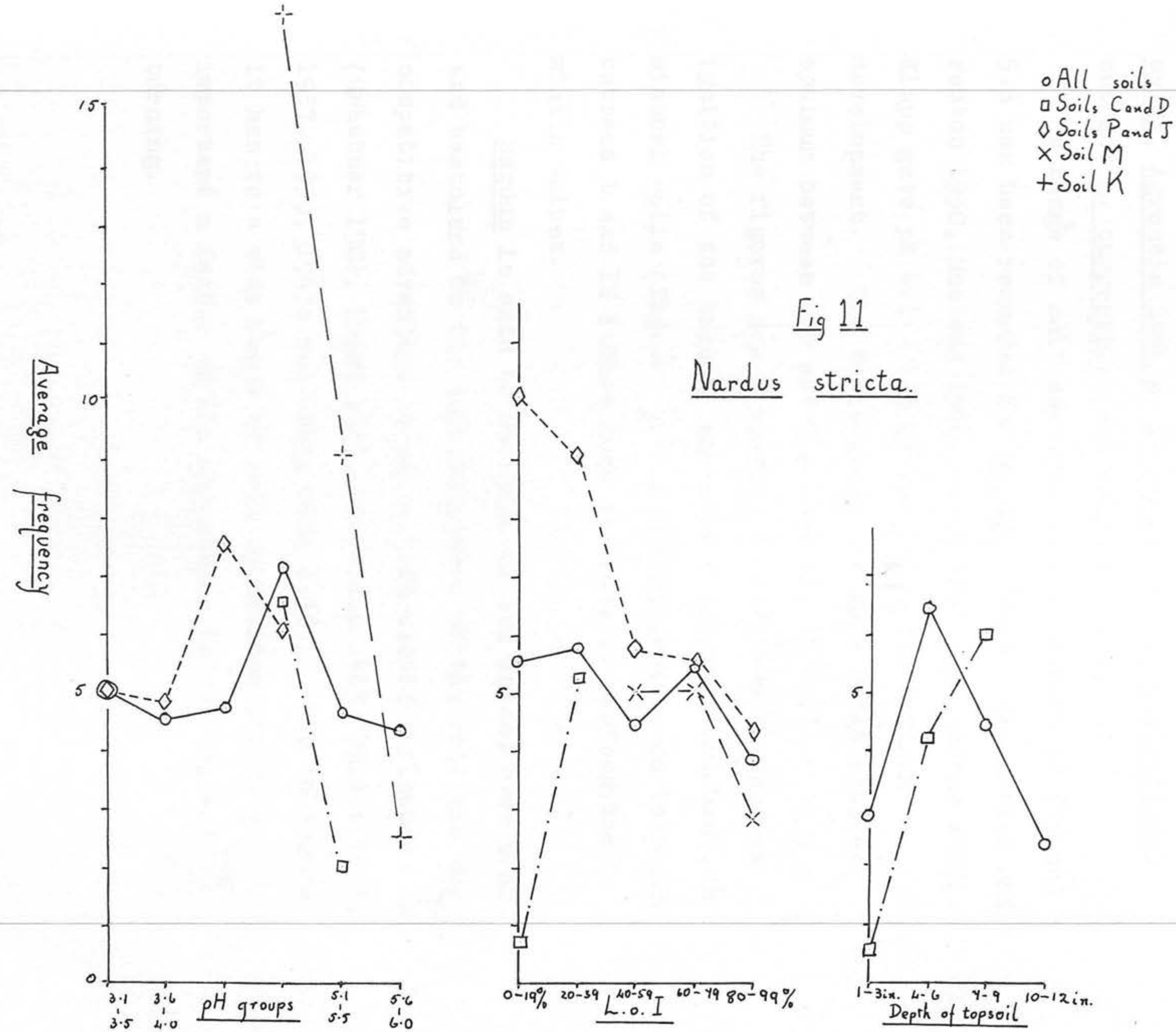


Fig 11

Nardus stricta.

situations to Agrostis stolonifera and Luzula campestris but here its place is taken, between the rush tussocks, by a consortium consisting of Holcus lanatus, Festuca ovina, Agrostis tenuis, A. canina and A. stolonifera, but not L. campestris (see Table 55, p.362).

A range of soil reaction values between pH 3.5 and 5.8 has been recorded for Nardus (Domin 1926, Atkins and Fenton 1930, Macleod 1948, Klapp 1951, Ballantyne 1953). Klapp gave pH 4.1 - 4.3 as the value for optimum development. The table shows the same range with an optimum between 4.0 and 5.0 (see fig. 11).

The figures for frequency in relation to loss on ignition of the topsoil may show a slight association with mineral soils (fig. 11). Although growing on topsoils between 1 and 12 inches deep it probably prefers the middle values.

Nardus is said to owe most of its spread over moor and heathland to the impoverishment of the soil and the competitive advantage it gains from biotic influences (Graebner 1901, Brown 1915, De Coulen 1923, Fenton 1933, 1937, 1939, 1947a and 1949, King 1955). The tolerance it has to a wide range of soil conditions may be as important a factor as its resistance to grazing and burning.

Molinia caerulea

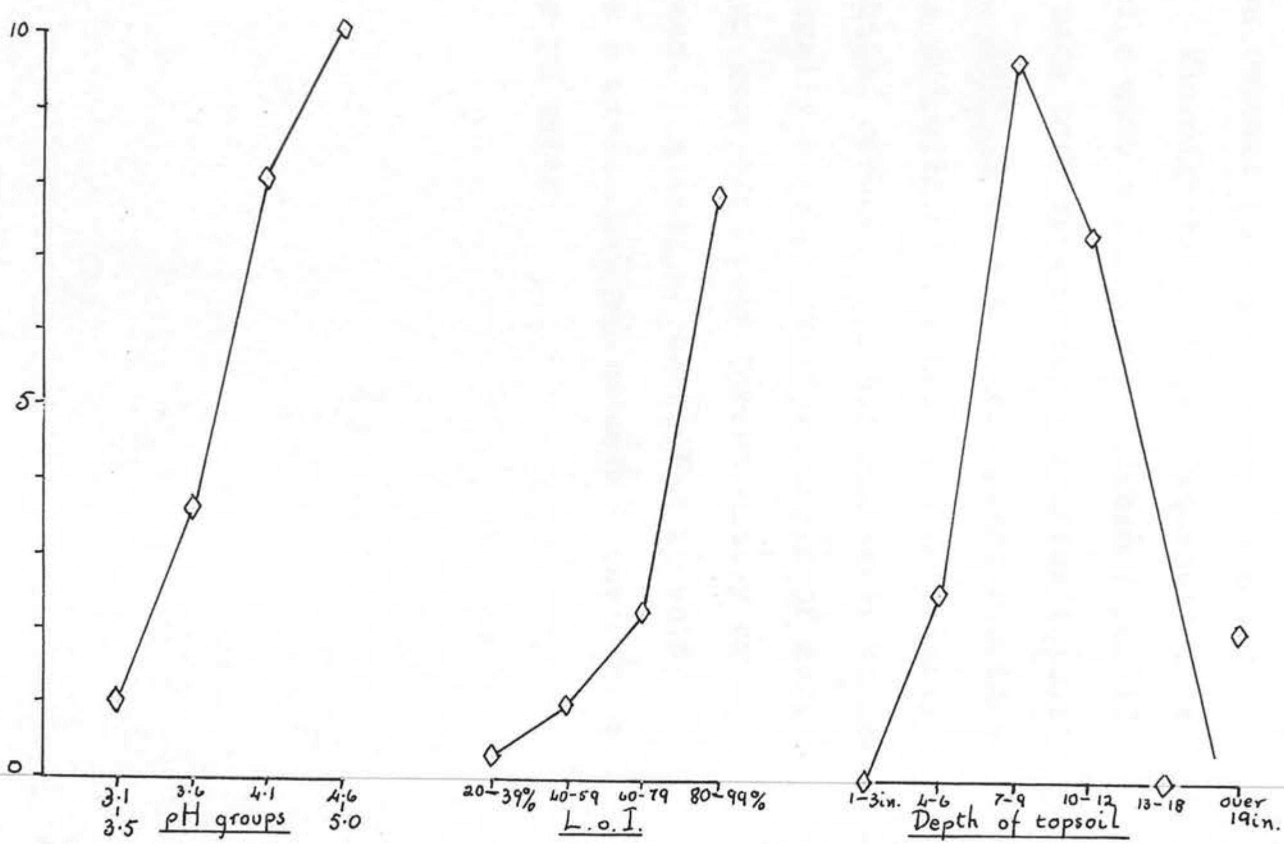
Soil type	Total Frequency	Average Frequency
M	76	8.4
J	203	7.3
O	6	1.5
P	10	0.6

	P	J	O	M	PJOM
pH group					
3.1 - 3.5		3.0	0		1.0
3.6 - 4.0	0	6.5	3.0	6.25	3.6
4.1 - 4.5	3.3	8.3		10.2	8.0
4.6 - 5.0		10.0			10.0
L. o. I.					
0 - 19%		16.0			16.0
20 - 39	0.4	0			0.3
40 - 59	0	0		4.0	1.0
60 - 79	1.3	3.0		0	2.2
80 - 99	0	11.2	1.5	12.0	7.8
Soil depth					
1 - 3	0	0			0
4 - 6	0.7	5.0		0	2.5
7 - 9	0	10.2		13.7	9.6
10 - 12		8.0		7.0	7.3
13 - 18			0		0
over 19			2.0		2.0

Blue moor grass or flying bent is a plant of wet places (Jeffreys 1917) which is capable of dominance provided the soil water is moving and aerated (Jefferies 1915). McVean (1951) has shown that vertical or horizontal movement of the soil water is essential for the development of Molinietum and Rutter (1955) found it needed a high and fluctuating water table. In Scotland Molinia is confined to acid peaty soils (Smith 1916, Fraser 1940), often being associated with a wet peaty top over a clay subsoil (Smith 1904). It is a peat forming plant, especially in southern Scotland where appreciable depths of a soft brown amorphous mor may accumulate below it. The requirement for peat and a high fluctuating water table can be met in two soils in the Lammermuirs, the podzolic gley and the podzol with a gleyed A_2 horizon. Both return high figures of average frequency. It is recorded as a dominant or abundant plant in both these soils and no others in different parts of southern Britain by Jacks (1932), Ogg (1935), Pearsall (1950), Muir (1955) and Mitchell and Jarvis (1956). In northern and western Scotland it is replaced by other species, usually ling, crossleaved heath, drawmoss and deer hair grass (Muir 1935, Fraser 1933 and 1936, Muir and Fraser 1939). Only in Wales is it recorded as growing on any other soil type, a poorly drained non-calcareous gley (Hughes 1949).

Flying bent grows on soils with a wide range of pH

Fig 12 Molinia coerulea Soils P J O and M



values (Olsen 1925, Small 1954). Scottish records are usually from the more acid soils (Fraser 1933, Ogg 1935, Ballantyne 1953) and it is so in East Lothian. The table however shows a clear positive correlation between pH and average frequency (fig. 12).

If the figure for the 0 - 19% group, which is based on a single record, can be disregarded there is evidence of an association between Molinia and high organic matter content. The highest average frequencies are recorded from soils with a mor layer between 7 and 12 inches deep and none from those with a shallow topsoil.

In Scotland, Molinia is a moorland plant confined to podzolic soils and, within this group, particularly to those with a high, strongly fluctuating water table. The topsoil is usually a well developed layer of mor, often a soft brown amorphous peat formed wholly or partly by the grass. Although restricted to acid habitats it shows a marked association with those of a relatively higher pH value.

Eriophorum vaginatum

Soil type	Total Frequency	Average Frequency
O	57	14.25
M	16	1.77
J	22	0.79

	J	O	M	JOM
pH group				
3.1 - 3.5	1.0	13.5		9.3
3.6 - 4.0	0.1	15.0	3.75	2.2
4.1 - 4.5	2.0		0	1.3
4.6 - 5.0	0		0	0
L. o. I.				
0 - 19%	0			0
20 - 39	0			0
40 - 59	0		0	0
60 - 79	0.2		1.0	0.3
80 - 99	1.4	14.3	2.3	3.8
Soil depth				
1 - 3	0			0
4 - 6	1.6		0	1.5
7 - 9	0.3		5.0	1.2
10 - 12	0		0	0
13 - 18		10		10
over 19		15.7		15.6

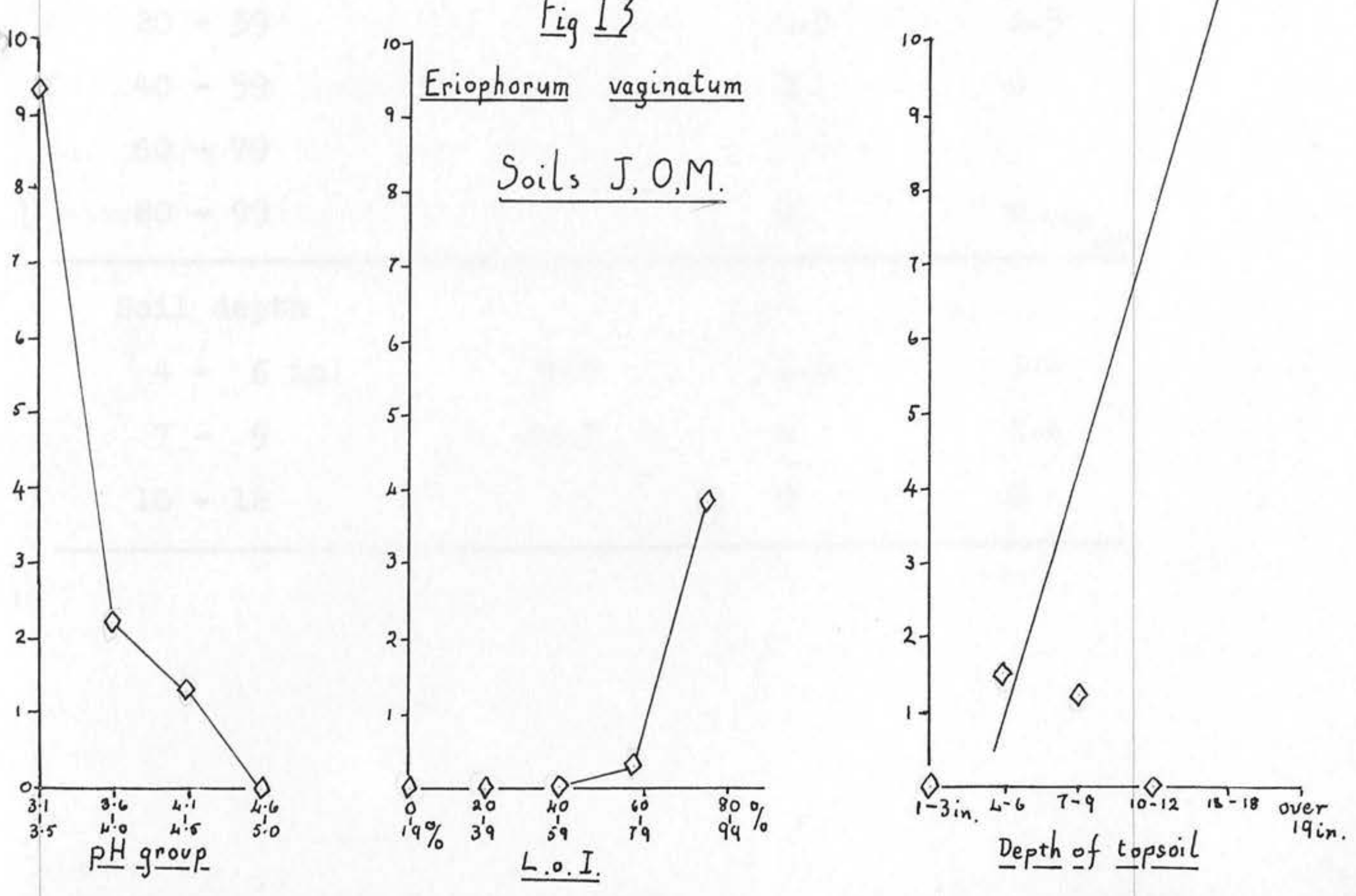
Draw moss is not a truly dominant species on any part of the area surveyed but forms a constant and conspicuous part of a Calluna community on flattish hill tops and in low basins. It has long been associated with deep peats with high and stagnant water tables at elevations of 1,000 ft. and more (Smith 1904, Jefferies 1915, Jacks 1932, Ogg 1935, Muir and Fraser 1939, Tansley 1939, Hughes 1949, Ballantyne 1953 and Muir 1955). Pearsall (1950) is of the opinion that E. vaginatum reaches high frequencies in the vegetation not on wet undrained bog as stated by Smith (1916) but on land formerly cut for fuel and partially drained. The typical soil has been described by Adamson (1918) as a peat 2 - 30 ft. deep over a podzol with an iron pan some 2 - 3 inches below the base of organic horizon. In the Lammermuirs the podzols form a series from type P through type J with a gleyed A_2 horizon to type O with increasing wetness and depth of the mor layer. The basin type of peat occurs over fen peat, silt and blue clay but is almost identical with the hill peat in composition as it is in the vegetation they bear. Drawmoss is here almost confined to peat and returns a high frequency from it. Smaller amounts are found on the two moist podzolic soils, type J and type M.

E. vaginatum is an acidiphilous plant (Small 1954) with a limited tolerance to soil reaction, its range being given as 2.98 to 3.40 (Adamson 1918), 3.5 to 4.8

(Fraser 1933), and 3.6 to 3.9 (Ballantyne 1953). Gimingham (1949) places its limits at pH 2.8 and pH 4.8 with a usual range between 3.2 and 4.0. Here the occurrences lie between the 3.1 - 3.5 and the 4.1 - 4.5 groups with a marked negative correlation (fig.13).

Two authors, Adamson (1918) and Ballantyne (1953), have commented on its association with almost pure peat, the latter giving a figure for loss on ignition of 97% and over. The table and fig.13 show no records below the 60 - 79% group and the highest average frequency in the 80 - 99% group.

As expected, there is a close relationship between frequency and topsoil depth, the highest figures being returned for those soils with a mor layer greater than 13 inches.



Juncus articulatus

Soil type	Total Frequency	Average Frequency
K	59	7.4
L	1	0.3

	K	L	KL
pH group			
4.6 - 5.0	0	1.0	0.3
5.1 - 5.5	10	0	6.7
5.6 - 6.0	9.5	0	6.3
L. o. I.			
0 - 19%	7.4		7.4
20 - 39		0.5	0.5
40 - 59		0	0
60 - 79			
80 - 99		0	0
Soil depth			
4 - 6 in.	4.0	1.0	3.4
7 - 9	10.7	0	8.6
10 - 12		0	0

In the Lammermuirs Jointed Rush or Spret is a prominent plant of some _Nardus_ grasslands and may approach abundance or dominance in frequently flooded areas. It has been associated with poor soils flushed by springs or subject to flooding by streams (Smith 1916). Both Fraser (1936) and Hughes (1949) mention it as a characteristic plant, along with _Nardus_, of poorly drained non-calcareous gleys. Here it occurs almost entirely on this type of soil. There is a very low figure for the very poorly drained series and none on any other soil.

A species confined to a single soil type, when examined by the methods of this survey, will tend to show an association with soil factors characteristic of that particular soil type. All that can be inferred safely from the tables is that the lower limit of tolerance to soil pH may be around pH 5·0 and that it may prefer 7 to 9 inch deep soils rather than those between 4 and 6 inches.

Juncus communis

Soil type	Total frequency	Average frequency
K	17	2.13
L	58	14.5

	K	L	KL
pH group			
4.6 - 5.0	2.0	16.0	6.6
5.1 - 5.5	1.5	18.0	7.0
5.6 - 6.0	3.5	6.0	4.3

	K	L	KL
L. o. I.			
0 - 19%	2.0		2.1
20 - 39		11.5	11.5
40 - 59		20.0	20.0
60 - 79			
80 - 99		16.0	16.0

	K	L	KL
Soil depth			
4 - 6 inches	1.0	16.0	4.0
7 - 9	3.0	6.0	3.6
10 - 12	0	18.0	18.0

The common rush has been described in the Biological Flora of the British Isles (Richards and Clapham 1941) in two species, J. conglomeratus and J. effusus which do not differ much ecologically. These authors, as well as Pearsall (1950) and Mitchell and Jarvis (1956), have shown that both species are confined to waterlogged soils which have pH values ranging from 3.9 to 7.1. In this survey the aggregate species occurs only on the two non-calcareous gleys and comes to dominance only on the very poorly drained series. During the map survey clumps of rushes were seen on areas occupied by other soil types, but, on inspection, the actual site always proved to be in a local depression or near to a small spring.

J. communis covers the range of pH of the gley soils. There is a tendency to be found on more organic soils, confirming the observations of Smith (1904) that, in hill land, common rushes are frequently associated with deep black silty soils or soft brown grass peats.

Group 2: Abundant plants

Potentilla erecta

Soil type	Total Frequency	Average Frequency
K	57	7.7
C	27	5.4
D	28	4.7
S	13	3.3
P	38	2.1
M	19	2.1
J	49	1.8
OL	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			0			0
3.6 - 4.0		5.0	1.3	3.7		1.7
4.1 - 4.5	5.5	3.5	3.5	0.6		3.1
4.6 - 5.0	1.0	6.5	1.5		4.3	4.3
5.1 - 5.5	1.0	5.0			7.0	5.9
5.6 - 6.0					0.7	0.7
L. o. I.						
0 - 19	1.0	5.2	1.0		7.1	5.7
20 - 39	4.0	4.8	5.2		0	4.2
40 - 59			5.7	10.0	0	5.4
60 - 79			1.1	5.0		1.3
80 - 99			0.7	0.5		0.6
Soil depth						
1 - 3	1.0	3.8	1.3			2.5
4 - 6	1.0	7.2	2.7	2.0	7.2	3.9
7 - 9		0	0.4	2.0	4.2	1.6
10 - 12	0		1.5	0.2		0.4

The tormentil is a common plant of the drier heaths and moors (Smith 1904, Heddle and Ogg 1933, Muir and Fraser 1939), which has been observed to increase in density as the soil was dried out by improved drainage (Jeffreys 1917). Balme (1953), dealing with a series of freely drained soils, showed that the herb preferred brown forest soils to podzols. In Ayrshire the plant is common only on the moist brown forest soil, occasional in the podzolic soils and the very poorly drained non-calcareous gley and rare or absent in all others. Here, the greatest frequencies of tormentil are recorded from the two brown forest soils and the gley K. There is a moderate record of it from the scree and it is low on podzols and absent from peat and the gley L.

The soils on which it has been recorded have soil acidity values of 4.0 (Atkins and Fenton 1930), 4.2 to 5.9 (Balme 1953) and 4.2 to 5.6 (Ballantyne 1953). Its range has been given as pH 3.5 - 3.9 to pH 7.0 - 7.4 with a maximum frequency around pH 5.0 - 5.4. The table and fig. 14 show a steady rise from pH 3.1 - 3.5 to a maximum at pH 5.1 - 5.5 and a sharp drop to pH 5.5 - 6.0.

Ballantyne (1953) considered it a plant of "mineral" and "organic" soils, giving figures for loss on ignition between 12% and 86%. The table and fig. 14 show that although it grows on soils of all groups in this category it shows a marked increase in frequency with decreasing organic matter content on all soils.

There is a trend, shown in the tables, which suggests that tormentil is associated with shallow topsoils (fig. 14).

P. erecta is an acid tolerant plant preferring dry to moist but not the wettest mineral soils. Although of minor importance in peaty soils it is a constant feature of the drier series.

Potentilla erecta

All soils

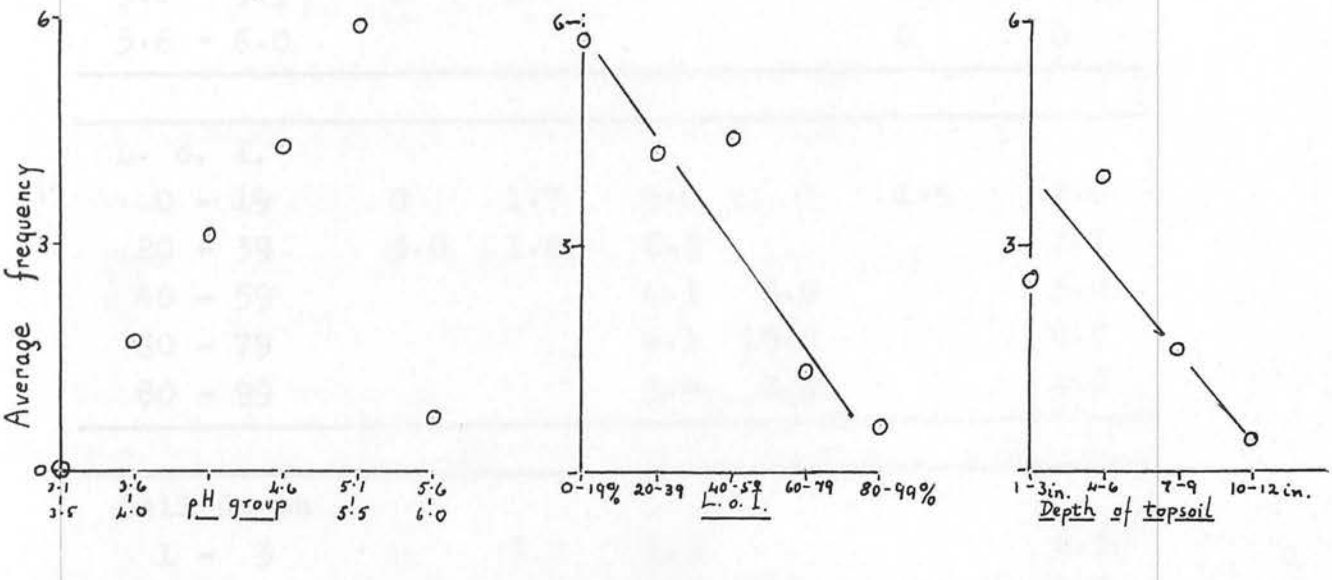


Fig. 14

Vaccinium myrtillus

Soil type	Total Frequency	Average Frequency
J	171	6.1
O	18	4.5
P	71	3.9
M	27	3.0
S	9	2.3
C	9	1.8
D	10	1.7
K	13	1.6
L	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			5.3			5.3
3.6 - 4.0		1.0	3.8	5.5		3.9
4.1 - 4.5	4.5	2.5	6.4	1.0		4.5
4.6 - 5.0	0	2.0	17.0		0.3	4.3
5.1 - 5.5	0	0			2.0	1.3
5.6 - 6.0					0	0
L. o. I.						
0 - 19	0	1.7	9.0		1.6	2.0
20 - 39	3.0	1.8	6.3			3.7
40 - 59			6.3	6.0		5.0
60 - 79			4.1	15.0		4.7
80 - 99			5.4	0.5		4.2
Soil depth						
1 - 3	0	2.2	1.3			1.5
4 - 6	0	1.6	6.6	0	2.6	5.8
7 - 9		0	3.3	5.3	0	2.7
10 - 12	8		12.5	2.2	0	4.4
13 - 18			12.0			12.0
over 19			2.0			2.0

The Biological Flora of the British Isles describes Blaeberry as a species, having as its natural habitat a pinewood or deciduous forest over a podzol, which has extended to the drier parts of heaths and moorlands (Ritchie 1956). Smith (1916) described it as a plant which cannot be suppressed on the steep rocky parts of hills. It is recorded from the drier peaty soils of the Pennines (Adamson 1918), the podzols over limestone in Derbyshire (Balme 1953) and all upland soils in Ayrshire except the non-calcareous gleys (Mitchell and Jarvis 1957). It is an important constituent of the vegetation over the drier brown forest soils (Heddle and Ogg 1933) and podzols (Heddle and Ogg 1933, Muir 1935, Ogg 1935, Muir and Fraser 1939 and Pearsall 1950). Here it attains its highest frequencies on the podzols and peat.

Authorities are agreed that this is a plant of acid places with a range of tolerance between 3.5 and 6.5 (Salisbury 1925, Ballantyne 1953, Small 1954 and Ritchie 1956). In their flushing experiments, Heddle and Ogg (1933) found it decreased as the pH rose from 4.6 to 6.0. The table and fig. 15 show a marked decrease in frequency as the value for the soil reaction rises from 3.1 - 3.5 to 5.6 - 6.0.

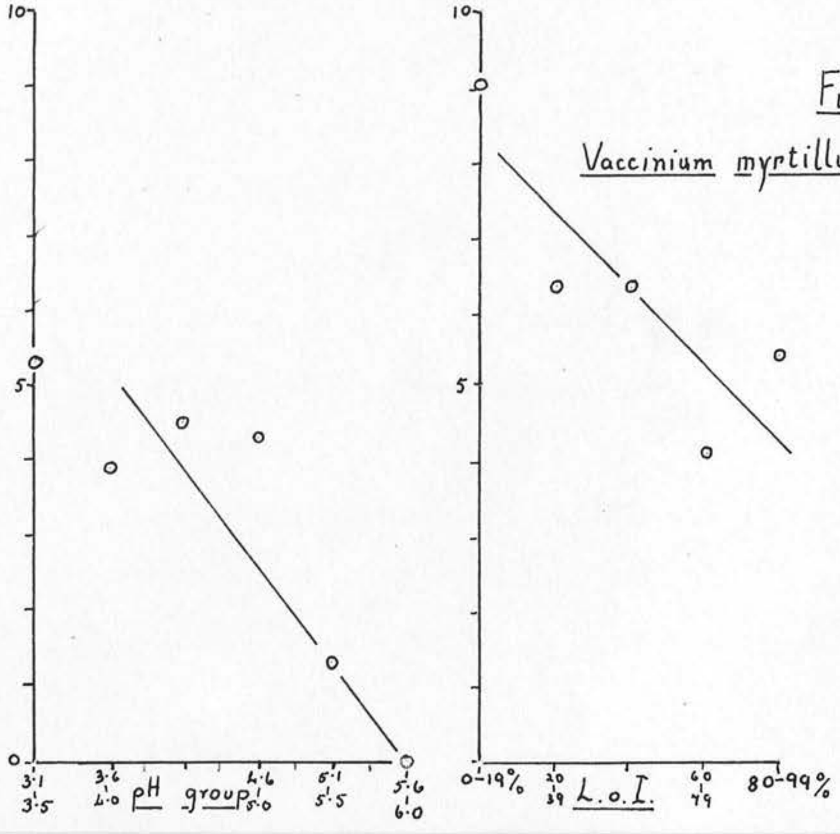
Although here found over the whole range of soil organic matter contents, as Ballantyne (1953) found in the Cheviots, there is in the podzol group, where it reaches its greatest abundance, a tendency to be found on those soils with a higher mineral content (fig. 15).

Gorham (1954) found that the occurrence of Blaeberry showed a strong positive correlation with the depth of the mor layer overlying the soil, between 0 and 4 inches. Although in this survey there is a comparatively low frequency in the 1 - 3 inch group the figures indicate an indifference to soil depth.

V. myrtillus is usually associated with dry heath soils, but here shows an association with the soils at the wetter end of the podzol range. Haines (1928b) calculated that of all the heath plants he examined it was the least capable of resisting drought. It may be that under the comparatively dry climate of East Lothian Blaeberry is forced to seek wetter soils than it may inhabit in other areas.

Fig 15

Vaccinium myrtillus



Galium hercynicum

Soil type	Total Frequency	Average Frequency
D	69	11.5
L	35	8.8
K	52	6.5
C	29	5.8
S	18	4.5
M	37	4.1
J	64	2.3
P	12	0.7
O	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			0			0
3.6 - 4.0		0	0.6	2.7		0.8
4.1 - 4.5	6.0	4.0	4.5	5.2		4.7
4.6 - 5.0	1.0	10.0			12.0	7.7
5.1 - 5.5	5.0	16.0			5.7	7.9
5.6 - 6.0					5.7	5.7
L. o. I.						
0 - 19%	5.0	7.7	0		6.5	7.4
20 - 39	4.3	10.4	2.4		7.5	5.7
40 - 59			5.3	7	5.0	5.6
60 - 79			1.4	0		1.3
80 - 99			0.9	5	0	1.9
Soil depth						
1 - 3	1.0	6.8	2.3			4.4
4 - 6	5.0	9.5	1.5	17.0	11.2	4.4
7 - 9		16.0	1.9	3.0	4.2	3.1
10 - 12	8.0		0	2.2	5.0	2.9

Heath bedstraw is described by Smith (1916) as a common coloniser of dry soils, which is true, but its range extends into the wettest terrestrial soils. Both Watt (1940) and Balme (1953) found it absent from rendzina-like soils but appearing at the earliest stage of leaching and increasing in abundance as podzolisation proceeded. In Ayrshire it has been recorded from brown forest soils, podzols and podzolic gleys but not from non-calcareous gleys or peat (Mitchell and Jarvis 1956). In this way bedstraw shows its highest frequencies on brown forest and non-calcareous gley soils; it is low on podzols and absent from peat.

The range of soil pH values in which the herb occurs has been given as 3.0 to 5.0 (Atkins and Fenton 1930), 3.8 to 5.1 (Ballantyne 1953) and 4.2 to 5.9 (Balme 1953). Olsen (1925) found it decreased in frequency between 3.5 - 3.9 and 5.5 - 5.9 as did Heddle and Ogg (1933) between 4.5 and 6.0, Watt (1940) between 3.8 and 6.2 and Balme (1953) between 4.2 - 4.8 and 5.8 - 6.9. Here the record shows a steady rise from 3.6 - 4.0 in all soils except the KL group which shows a decline between 4.6 - 5.0 and 5.6 - 6.0 (fig. 16).

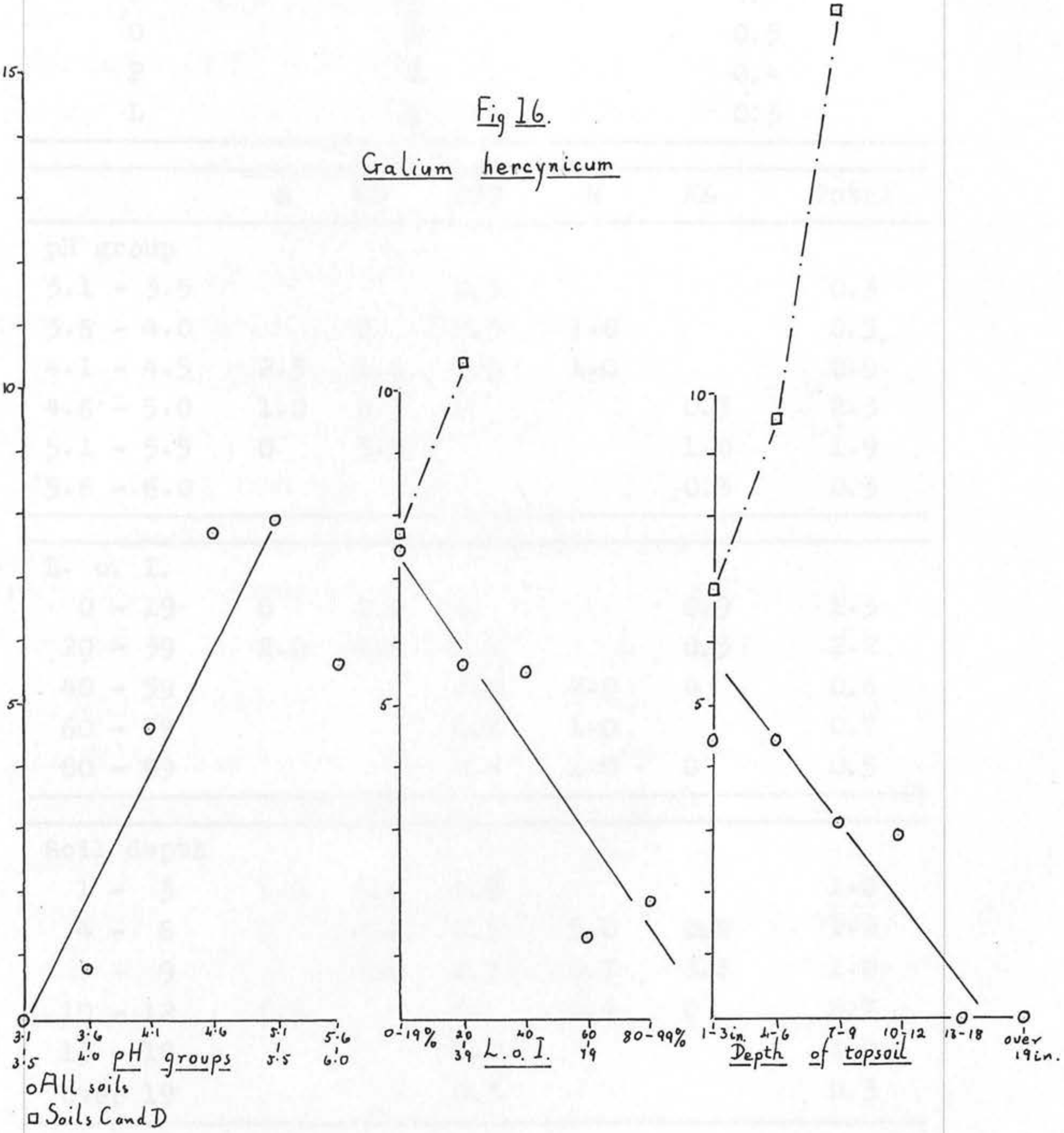
Over all soils there is a tendency to drop in frequency as the value for loss on ignition of the topsoil increases except in the case of brown forest soil where the trend is the other way.

The trend in soil depth also favours the shallow soils confirming the results obtained by Gorham in Irish soils where it occurs only when no mor layer is present. In the brown forest soils and screes, however, the trend runs markedly the opposite way.

This plant has a tolerance wide enough to cover most of the soils of heaths and the dryer moorlands. It does best on the mineral soils.

Fig 16.

Galium hercynicum



<u>Luzula campestris</u> agg. (<u>L. campestris</u> (L) D.C., <u>L. multiflora</u> (Retz.) Lej., and <u>L. pilosa</u> (L) Willd.)

Soil type	Total Frequency	Average Frequency
C	19	3.8
D	17	2.8
S	6	1.5
M	9	1.0
K	7	0.9
J	19	0.7
O	2	0.5
P	8	0.4
L	1	0.3

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			0.3			0.3
3.6 - 4.0		0	0.5	1.0		0.5
4.1 - 4.5	2.5	1.0	0.5	1.0		0.9
4.6 - 5.0	1.0	5.3	0		0.3	2.3
5.1 - 5.5	0	5.3			1.0	1.9
5.6 - 6.0					0.3	0.3
L. o. I.						
0 - 19	0	2.2	0		0.9	1.3
20 - 39	2.0	4.6	1.1		0.5	2.2
40 - 59			3.0	2.0	0	0.6
60 - 79			0.6	1.0		0.7
80 - 99			0.4	1.0	0	0.5
Soil depth						
1 - 3	1.0	0.8	0.8			1.0
4 - 6	0	4.2	0.5	5.0	0.8	1.2
7 - 9		8.0	0.7	0.7	0.8	1.0
10 - 12	5.0		0	0.4	0	0.7
13 - 18			1.0			1.0
over 19			0.3			0.3

The three small woodrushes of hill country are not quickly distinguished, the one from the other, during an extensive survey and have had here to be treated together as if they were a single species. Investigation of their different requirements may well show what the literature indicates, that each has a range of tolerance to soil factors distinct from the others.

In northern Scotland, Fraser (1940), names L. pilosa as a plant of dry heath and L. multiflora of wet heath. In south-west Scotland Mitchell and Jarvis (1957) found L. campestris was present on the brown forest soils, the podzols and the podzolic gley while L. multiflora was confined to non-calcareous gleys. Here the aggregate species has been recorded in low frequencies from every soil type but mostly from the brown forest soils and the scree. Very low figures were gained from the podzols and the gleys.

Olsen (1925) showed that L. multiflora rose in frequency between pH 4.0 and 5.0 - 5.4 then fell to 7.4 to 7.9. Ballantyne (1953) gave the range of L. campestris agg. as 3.9 to 5.6 and Small (1954) included L. multiflora and L. pilosa in his amphitolerant group (below 4.8 to above 7.0) and L. campestris in his mesophilous group (pH 4.8 to 7.2). Heddle and Ogg (1933) observed a decrease in the frequency of L. campestris when the soil pH was raised from 4.5 to 6.0 by flushing. The woodrushes here are found over the whole range but show an increase between 3.1 - 3.5 and 4.6 - 5.0 and a decrease to the 5.6 - 6.0 group (fig.17).

It is found in every humus type and in all proportions of organic and mineral matter. There is a negative relation between frequency and loss on ignition over all soils (fig.17) but in individual groups the highest figures appear between 20% and 59%.

Soil depth may have a slight negative relation with frequency but in the brown forest group (CD) it is positive, and in the podzolic gley, negative.

Luzula campestris comes nearer than any of the other species here mentioned to being indifferent to the soil types present on the area. Its range of tolerance allows it to be, although never common in the ecological sense, nearly ubiquitous. But then, this is a composite species and each one of the three may have narrower but overlapping limits to the range of soil factors under which it may live.

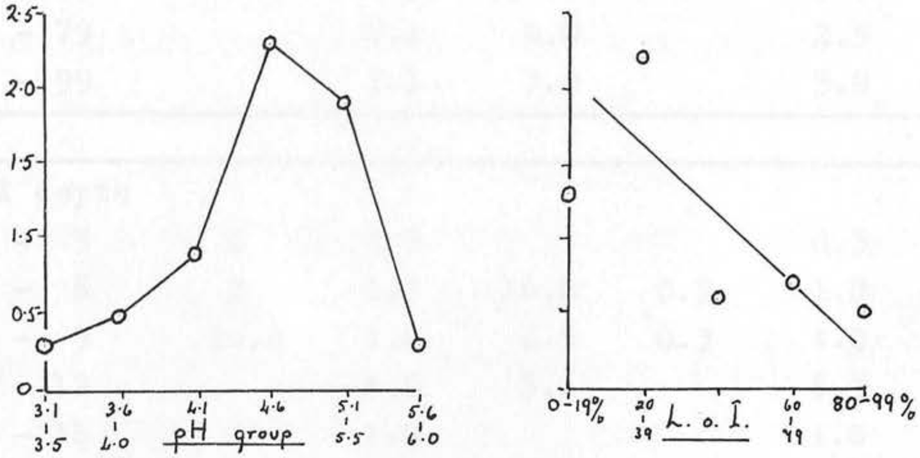


Fig 17

Luzula campestris

o All soils

Juncus squarrosus

Soil type	Total Frequency	Average Frequency
M	63	7.0
J	96	3.4
O	9	2.3
D	12	2.0
P	15	0.8
K	3	0.4
SCL	-	-

	D	PJO	M	K	DPJOMK
pH group					
3.1 - 3.5		1.0			1.0
3.6 - 4.0	0	2.5	6.5		2.9
4.1 - 4.5	0	1.6	7.4		2.7
4.6 - 5.0	6.0	7.5		0.5	4.7
5.1 - 5.5	0			0.5	0.4
5.6 - 6.0				0	0
L. o.I.					
0 - 19%	0	2.0		0.4	0.4
20 - 39	6.0	1.3			2.3
40 - 59		1.0	12.0		3.8
60 - 79		2.1	8.0		2.5
80 - 99		3.1	7.0		3.9
Soil depth					
1 - 3	0	0.5			0.3
4 - 6	0	1.5	16.0	0.5	1.8
7 - 9	12.0	4.0	6.5	0.3	4.0
10 - 12		4.5	5.6		5.3
13 - 18		1.0			1.0
over 19		2.7			2.7

The sites most usually occupied by the heath rush are described by Robert Smith (1904) as Nardus grassland over moist soil with a peaty top and wet hollows over a podzol in Calluna heath, often with Nardus. W.G. Smith (1916) found it on all kinds of poor soils, dry or peaty, Thomas (1936) on moist heath and Fraser (1940) on wet heath. Mitchell and Jarvis (1956) recorded it from podzols, podzolic gleys and the poorly drained non-calcareous gley. In this study the highest frequencies are recorded from the brown podzolic gley followed by the podzol J, peat and the moist brown forest soil. It is low on the dry podzol, P, and the gley K.

The table and fig.18 show its pH range as from 3.1 - 3.5 to 5.1 - 5.5 with a maximum about 4.6 - 5.0. Most of the pH values below 5.0 come from brown forest and podzolic soils which show a tendency to positive relation between pH and frequency. Those above come from the gleys therefore some other factor may be operating to reduce the heath rush.

Ballantyne (1953) states that it is confined to organic soils with a loss on ignition value between 81 and 89%. Here it is found on all groups but the trend is for the higher frequencies to be found on the upper part of the range. Although found in soils of all depths it has a negligible frequency on the 1 - 3 inch group and a maximum around 7 - 12 inches, probably a reflection of the high frequencies on the podzolic gley.

This is a plant tolerant of acidity in moist to wet soils, mostly on peat or mor and less often on moders. It is therefore mainly associated with podzols and peat. It does not develop well in dry soils, either mineral or podzolic, and the high frequencies on soil types M and J suggest an association with a situation where the water table fluctuates. Significantly its only appearance on a moder soil with a pH over 5.0 is on soil with such a water table, the poorly drained non-calcareous gley.

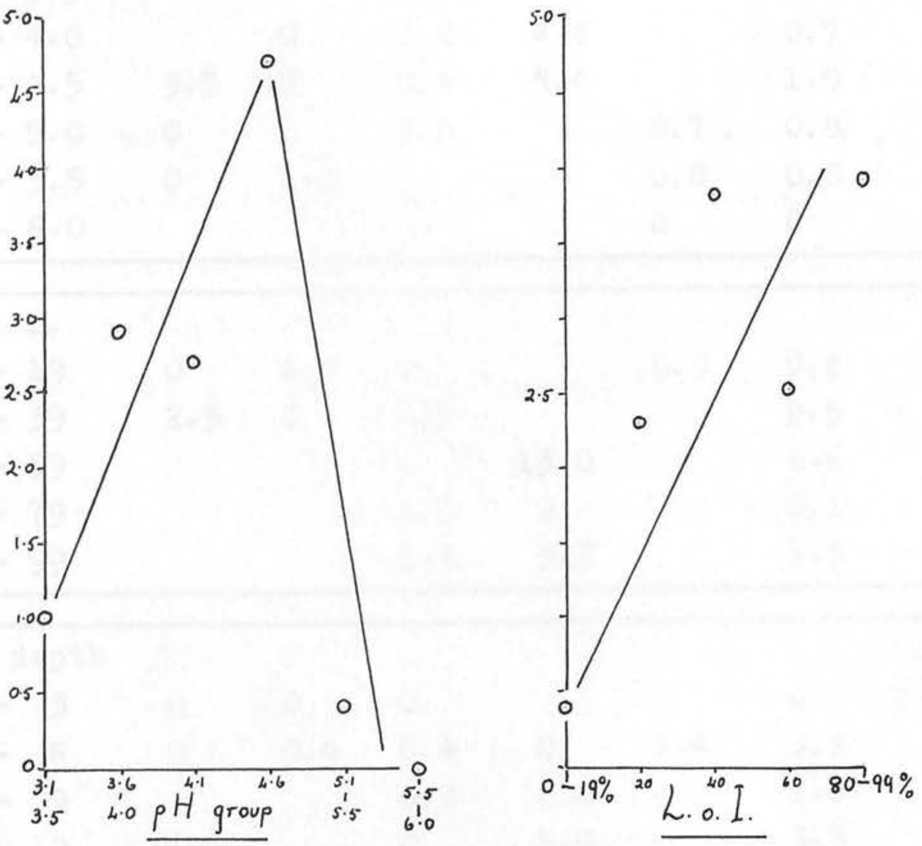


Fig. 18

Juncus squarrosus o All soils

Carex nigra

Soil type	Total Frequency	Average Frequency
M	47	5.2
O	14	3.5
S	7	1.8
K	7	0.9
J	12	0.4
C	2	0.4
P	3	0.2
DL	-	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			3.7			3.7
3.6 - 4.0		0	0.2	4.8		0.7
4.1 - 4.5	3.5	0	0.8	5.6		1.9
4.6 - 5.0	0	0	3.0		0.7	0.8
5.1 - 5.5	0	1.0			0.8	0.8
5.6 - 6.0					0	0
L. o. I.						
0 - 19	0	0.3	0		0.9	0.6
20 - 39	2.3	0	0.7			0.5
40 - 59			0	13.0		2.6
60 - 79			0.1	0		0.1
80 - 99			1.2	3.2		1.5
Soil depth						
1 - 3	0	0	0			0
4 - 6	0	0.4	0.4	0	1.4	0.5
7 - 9			0.3	6.0	0	1.0
10 - 12	6.0		0	5.8		3.5
13 - 18			0			0
over 19			4.7			4.7

A common sedge of moorland growing mainly in podzolic and acid soils, but also occurring in non-calcareous gleys in hill land (Mitchell and Jarvis 1956). Here it is most frequently found on the podzolic gley and peat. Occasional plants are recorded from every soil type but two.

Olsen (1925) gave its pH range as 3.5 to 7.9 with a maximum frequency recorded between 4.5 and 5.9. Small (1954) agrees with this by placing it in his amphitolerant group. Here it ranges from 3.1 - 3.5 to 5.1 - 5.5 and its frequency is negatively correlated with soil reaction.

It is found in every type of topsoil and may prefer the deeper sites.

This plant has a wide range of tolerance to soil type. The apparent association with acid and deep soils is probably only a reflection of the high values returned from soils O and M and the low values from others.

Deschampsia flexuosa

Soil type	Total Frequency	Average Frequency
M	98	10.9
S	29	7.3
C	32	6.4
J	176	6.3
P	96	5.3
D	16	2.7
K	12	1.5
O	5	1.3
L	0	-

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			1.7			1.7
3.6 - 4.0		12.0	4.3	8.3		5.7
4.1 - 4.5	11.5	2.3	8.2	13.0		8.5
4.6 - 5.0	3.0	4.8	9.0		1.7	4.4
5.1 - 5.5	3.0	4.0			1.2	2.0
5.6 - 6.0					0	
L. o. I.						
0 - 19%	3.0	2.8	6.0		1.5	2.4
20 - 39	8.7	6.2	3.4		0	4.8
40 - 59			9.3	10	0	7.6
60 - 79			4.6	9		4.9
80 - 99			5.9	12	0	6.9
Soil depth						
1 - 3	3.0	4.3	2.8			3.5
4 - 6	3.0	4.0	6.7	9.0	2.4	5.7
7 - 9		7.0	5.8	13.3	0	5.2
10 - 12	14.0		3.0	9.0	0	6.9
13 - 18			1.0			1.0
over 19			1.3			1.3

Wavy hair grass is commonly associated with shallow dry soils. It has been recorded as a major constituent of the vegetation over dry brown forest soils by Jefferies (1917), Adamson (1918), Heddle and Ogg (1933), Pearsall (1950) and Ballantyne (1951 and 1953), and over podzols equivalent to type P by Fraser (1936), Muir and Fraser (1940), Ballantyne (1953) and Mitchell and Jarvis (1956). It is reported from the dry tops of tussocks in Eriophorum peat by Scurfield (1954). Here, as in Ayrshire (Mitchell and Jarvis 1956), the highest frequencies are found in the podzolic gley, a moist, moderately deep peaty soil. Nearly every soil bears it, but the higher frequencies are found on the scree, the dry brown forest soil and the two podzols, all subject to summer drought even if not dry. The moist and wet soils, both "mineral" and "organic", return lower figures.

Muir and Fraser (1939) considered this a grass of soils with pH values below 4.0 and Small (1954) places it in his acid tolerant B group (below pH 4.8 to between 5.5 and 7.0). Negative correlations have been found between frequency and soil reaction in the range 3.5 - 3.9 to 4.5 - 4.9 (Olsen 1925) and 3.2 to 5.0 (Jowett and Scurfield 1949b). A rise in the pH of heath soil from 4.6 to 6.0 caused by flushing with basic water was accompanied by a decrease in the frequency of D. flexuosa (Heddle and Ogg 1933). The table and fig.19

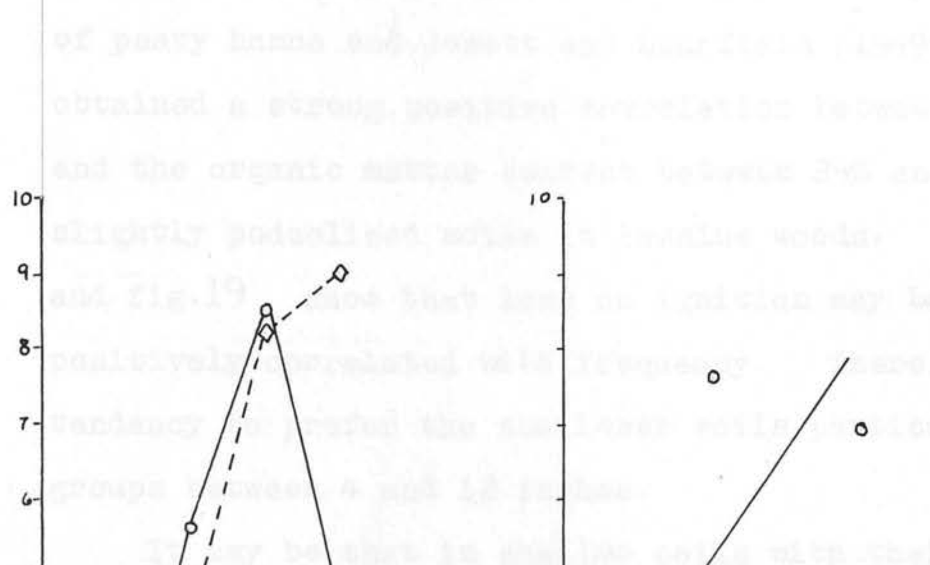


Fig 19

Deschampsia flexuosa

o = All soils

◊ = Soils P, J, O.

show a range from 3.1 - 3.5 to 5.1 - 5.5 with maximum frequencies about 4.1 - 4.5. In podzolic soils there is a positive correlation with increasing pH and there may be the same in brown forest soils.

Tansley (1939) regards it as principally a grass of peaty humus and Jowett and Scurfield (1949b) obtained a strong positive correlation between frequency and the organic matter content between 25% and 90% on slightly podzolised soils in Pennine woods. The table and fig.19 show that loss on ignition may be positively correlated with frequency. There is also a tendency to prefer the shallower soils particularly the groups between 4 and 12 inches.

It may be that in shallow soils with their often patchy vegetation cover, Wavy-hair Grass is an important part of the vegetation although occurring in relatively lower frequencies while in podzolic gleys with close cover it is a less important constituent but occurs in higher frequencies. Descriptive ecology would tend to associate the species with the soils on which it plays an important part while this type of survey selects out those soils on which the species reaches its greatest abundance.

<u>Agrostis canina</u> agg.

Soil type	Total Frequency	Average Frequency
L	20	5.0
K	35	4.4
C	19	3.8
D	12	2.0
J	41	1.5
M	5	0.6
P	7	0.4
OS	-	-

	CD	PJ	M	KL	Total
pH group					
3.1 - 3.5		0			0
3.6 - 4.0	3.0	0.6	0.8		0.7
4.1 - 4.5	1.3	2.0	0.4		1.5
4.6 - 5.0	2.5	2.0		6.0	3.6
5.1 - 5.5	7.5			5.8	6.0
5.6 - 6.0				0.7	0.7

	CD	PJ	M	KL	Total
L. o. I.					
0 - 19%	2.3	0		4.4	3.3
20 - 39	3.4	0.9		1.0	1.8
40 - 59		2.3	0	17.0	4.8
60 - 79		1.4	3.0		1.5
80 - 99		0.7	0.3	1.0	0.6

	CD	PJ	M	KL	Total
Soil depth					
1 - 3	0.6	1.0			0.8
4 - 6	4.0	1.2	2.0	4.4	2.1
7 - 9	8.0	0.9	1.0	2.8	1.6
10 - 12		0	0	9.5	1.9

A study of the distribution of brown bent is complicated by the presence of two sub-species, A. canina canina and A. c. montana. The first of these is said to prefer soils of higher base status and the latter a drier, more acid substrate (Hubbard 1953). A. canina agg. has been recorded from most types of heath vegetation on a variety of soils, sometimes with A. tenuis as Agrostis spp. (Heddle and Ogg 1933, Fraser 1940, Muir and Fraser 1939, and Hughes 1949). In a range of freely drained soils Balme (1953) found Agrostis spp. on the brown forest soils and incipient podzols only. In Ayrshire it is present on all soil types but reaches importance only in the brown forest and gley soils (Mitchell and Jarvis 1956). The same findings are made here, for the records for podzols are very low and it is absent from screes and peat.

Small (1954) considers it an "acid tolerant" grass and Olsen (1925) gives its range as pH 4.0 to 6.4. Ballantyne (1953) recorded it between 3.9 and 5.7 (Agrostis spp.) (see fig. 20).

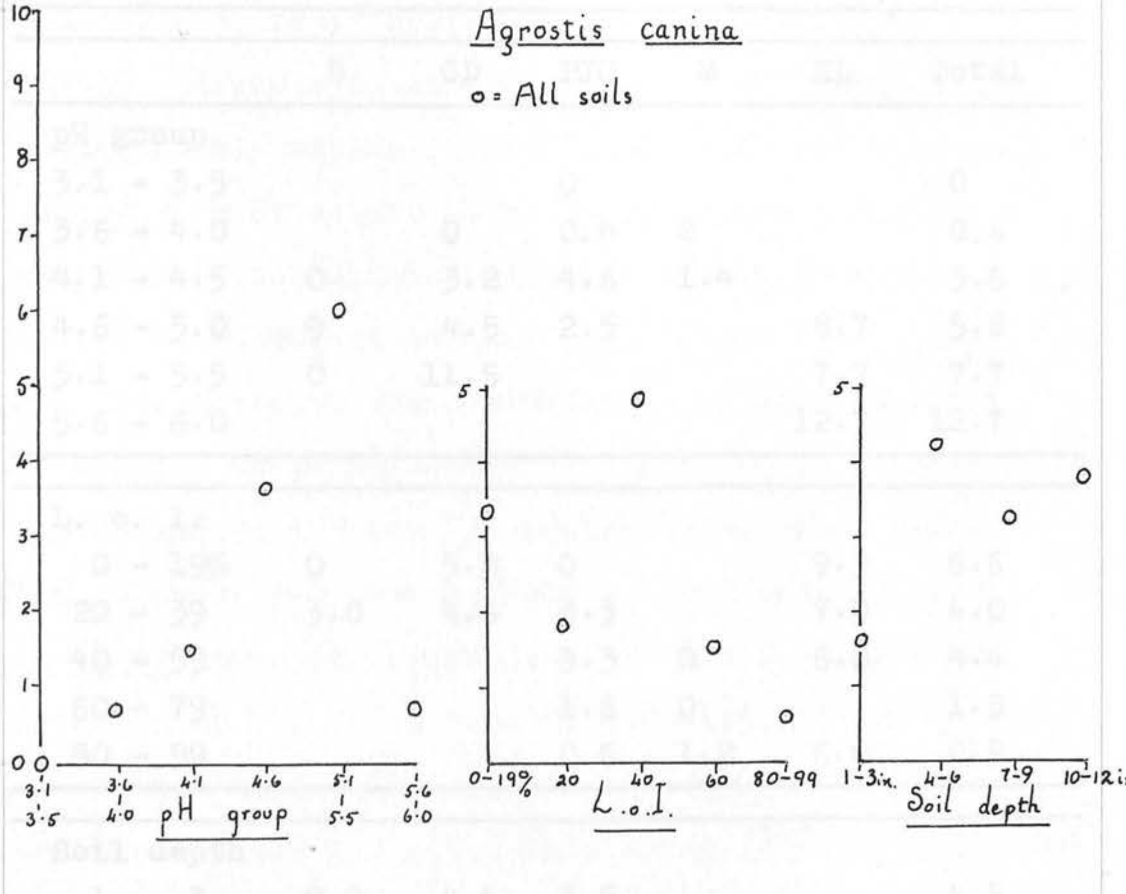
Although the table shows it growing on every type and composition of topsoil it probably prefers those with a moder humus and a loss on ignition value below 60%.

It is absent from the deeper peats and low on the shallowest soils (fig. 20).

Although a less important species than A. tenuis,

A. canina is almost as widespread. It shows a preference for mineral, less acid soils and is capable of spanning the whole range of soil moisture conditions excepting the very driest.

Fig 20



Anthoxanthum odoratum

Soil type	Total Frequency	Average Frequency
K	74	9.3
L	36	9.0
D	36	6.0
C	18	3.6
J	66	2.9
S	9	2.3
M	7	0.8
P	11	0.6
O	1	0.3

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			0			0
3.6 - 4.0		0	0.4	0		0.4
4.1 - 4.5	0	3.2	4.6	1.4		3.6
4.6 - 5.0	9	4.5	2.5		8.7	5.8
5.1 - 5.5	0	11.5			7.7	7.7
5.6 - 6.0					12.7	12.7
L. o. I.						
0 - 19%	0	5.3	0		9.3	6.6
20 - 39	3.0	4.4	3.3		7.0	4.0
40 - 59			5.3	0	6.0	4.4
60 - 79			1.6	0		1.5
80 - 99			0.6	1.2	6.0	0.9
Soil depth						
1 - 3	9.0	4.4	3.5			4.5
4 - 6	0	5.2	1.5	7.0	9.2	3.2
7 - 9		6.0	1.3	0	10.4	3.2
10 - 12	0		0	0	6.0	1.2
13 - 18			0			0
over 19			0.3			0.3

Sweet vernal grass has been mentioned as an inhabitant of a wide variety of soil types but never as a dominant (Tansley 1939). Mitchell and Jarvis (1956) confirm this observation for Ayrshire soils but noted lower frequencies on peats and podzols than on other types. In Breckland this grass ~~prefers~~ is associated with slightly podzolised soils to rendzinas or more fully developed types (Watt 1940), but in Derbyshire it is indifferent to soil type between rendzina, brown earth and incipient podzol, all freely drained series (Balme 1953). Sweet vernal increases in abundance as soils become progressively wetter (Jefferies 1917). On the eastern Lammermuirs it occurs in every soil type but most abundantly on the two non-calcareous gleys and less so on the brown forest soils.

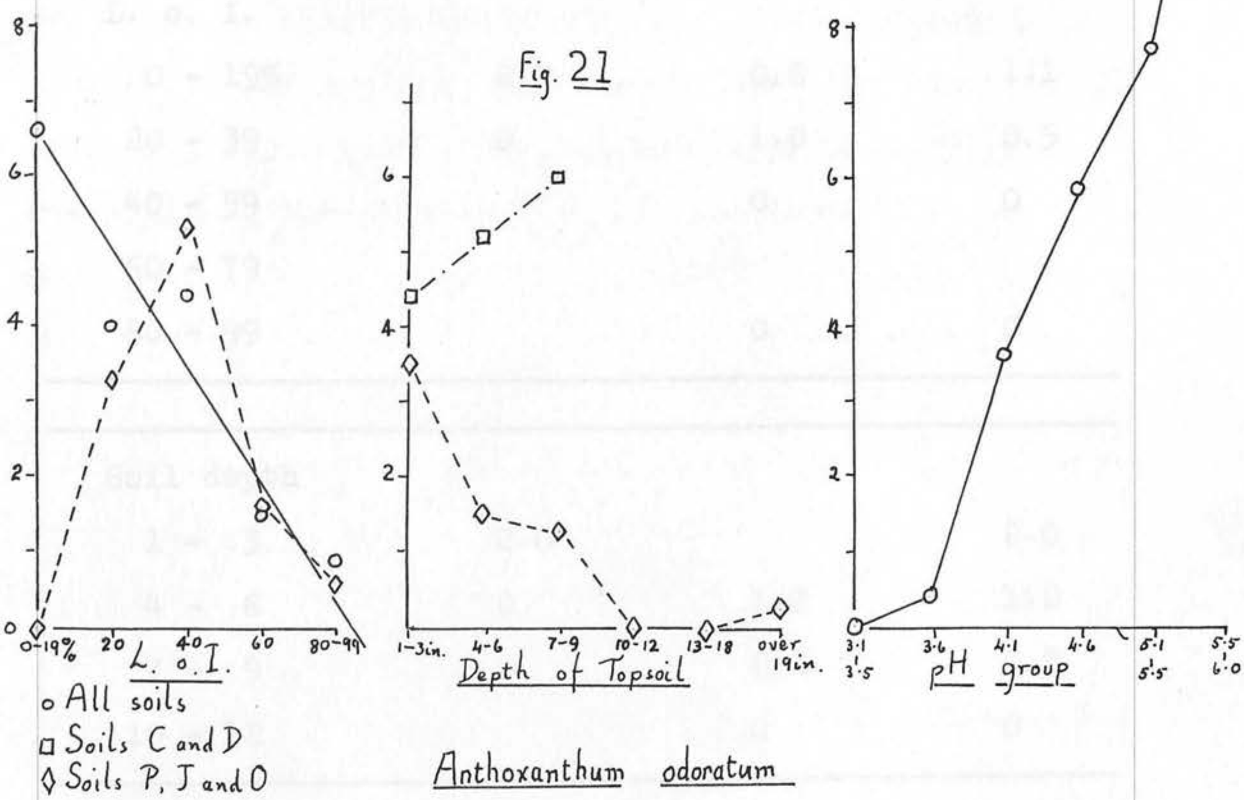
The grass covers a wide range of soil reaction values, being found between 4.0 and 7.0 (Atkins and Fenton 1930), 4.2 and 7.5 (Balme 1953), and from below 4.8 to above 7.0 (Small 1954). In Denmark it has been shown to increase in frequency as the soil pH rises, from 3.5 to 5.0 - 5.9 then to decrease to 7.0 - 7.9. In Breckland (Watt 1940), the increase takes place between 4.0 and 6.2 - 7.8 from there decreasing to 8.2. Here, over all soils, there is an increase in frequency as the pH value rises from a low figure at 3.6 - 4.0 to 5.6 - 6.0 (fig. 21).

The table and fig. 21 bring out the association with "mineral" rather than "organic" soils, a trend apparent even in the podzols.

Over all soils there is ~~a preference for~~ an association with the shallower soils rather than the deeper types. Within the groups with moder upper horizons the ~~preference~~ association is for 7 - 9 inch depths rather than shallower or deeper but in the podzols with mor topsoils the shallowest provide the largest frequencies (fig.21) and). In Irish woodlands, Gorham (1954) found the same relationship with depth of the mor layer.

The figures bring out a picture of the grass as tolerant of a wide range of soil conditions but with an association with moder to mor topsoils and becoming increasingly abundant as the soils get wetter or their pH values rise.

Fig. 21



Anthoxanthum odoratum

Group 3: Plants of moderate frequency

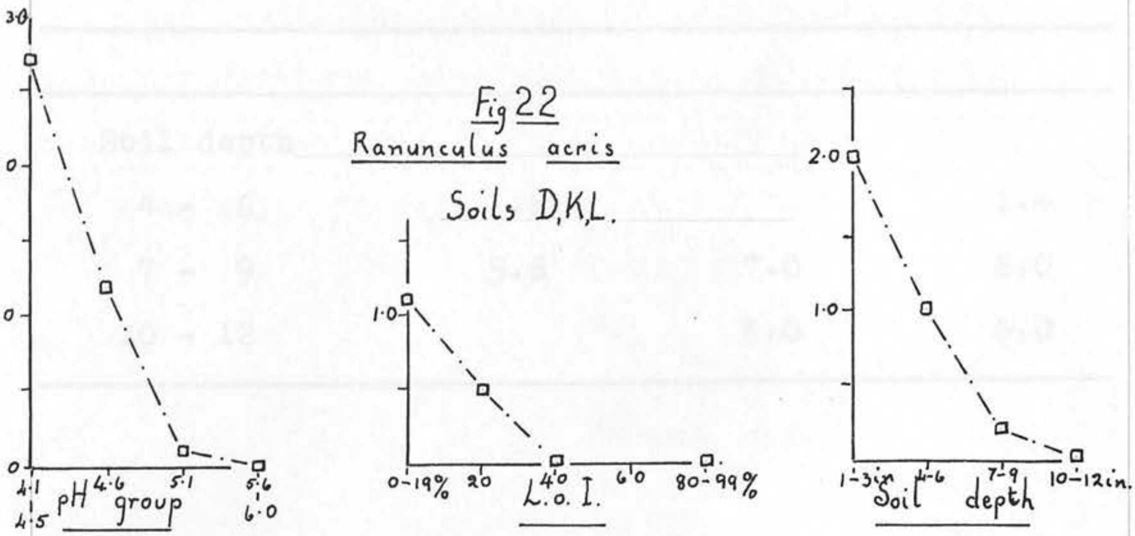
Ranunculus acris

Soil type	Total frequency	Average Frequency
D	8	1.3
K	5	0.6
L	2	0.5

	D	KL	DKL
pH group			
4.1 - 4.5	2.7		2.7
4.6 - 5.0	0	2.0	1.2
5.1 - 5.5	0	0.2	0.1
5.6 - 6.0		0	0
L. o. I.			
0 - 19%	2.0	0.6	1.1
20 - 39	0	1.0	0.5
40 - 59		0	0
60 - 79			
80 - 99		0	0
Soil depth			
1 - 3	2.0		2.0
4 - 6	0	1.2	1.0
7 - 9	0	0.2	0.2
10 - 12		0	0

Bitter buttercup is less frequent on uplands than is R. repens and usually occurs on drier and less acid soils (Harper 1957). The data in the table bear out the first part of this statement. The limits of tolerance of this plant to soil reaction have been given as 4.0 to 7.8 (Small 1954) and 6.6 to 8.3 (Harper and Sagar 1953) and Olsen (1925) determined that its frequency showed a positive relationship to pH between 5.0 and 7.0 - 7.4. Here it is found between 4.1 and 6.0 with a negative correlation which may, however, be a reflection of the fact that in this area dry soils are more acid than wet ones and the plant is found on the relatively dry sites.

There is also a negative correlation with loss on ignition and with soil depth (see fig. 22) and again the shallow mineral soils are usually the driest. The evidence does suggest that a preference for moist rather than wet soils prevails over some other factors in determining the distribution of this herb.



Ranunculus repens

Soil type	Total Frequency	Average Frequency
L	19	4.8
K	30	3.8

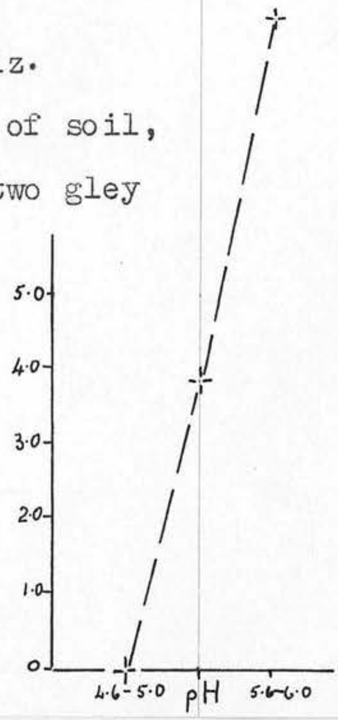
	K	L	KL
pH group			
4.6 - 5.0	0		0
5.1 - 5.5	2.8	6.0	3.8
5.6 - 6.0	9.5	7.0	8.7
L. o. I.			
0 - 19	3.7		3.7
20 - 39		3.5	3.5
40 - 59		7.0	7.0
60 - 79			
80 - 99		5.0	5.0
Soil depth			
4 - 6	1.8		1.4
7 - 9	5.8	7.0	6.0
10 - 12		6.0	6.0

Creeping buttercup is a herb of the wettest sites in pastures (Harper and Sagar 1953, Harper 1954). It is found on a wide range of soils but mostly on heavy wet ones. When it grows on the peat of upland grasslands this invariably proves to be the grass peat of Juncetum and never moorland or dry peat (Harper 1957). In Ayrshire it is found most frequently on the poorly drained non-calcareous gleys and sometimes on the very poorly drained series, and occasionally on brown forest soils and cultivated podzolic gleys (Mitchell and Jarvis 1956). In the Lammermuirs, R. repens is confined to soil types K and L, the figures for each being similar.

From the table and fig. 23 the herb is obviously at the lower end of its range of tolerance to soil reaction in the 5.1 - 5.5 group. A wide range of loss on ignition values is embraced, those in the higher ranges coming from the grass peat of Juncetum. It grows on soils between 4 and 12 inches deep, possibly preferring those over 7 inches.

The conditions required by this plant, viz. abundant moisture, high base status and depth of soil, can only be satisfied in hill country on the two gley soils to which it is confined.

Fig 23
Ranunculus repens
Soils K, L.



Viola riviniana

Soil type	Total Frequency	Average Frequency
C	9	1.8
D	10	1.7
K	12	1.5
S	1	0.3

	S	C	D	K	CD	CDK
pH group						
3.6 - 4.0		1.0			1.0	1.0
4.1 - 4.5	0	1.0	1.3		1.2	1.2
4.6 - 5.0	0	0.5	1.5	0	1.0	0.7
5.1 - 5.5	1.0	6.0	3.0	2.5	4.5	3.3
5.6 - 6.0				1.0		1.0
L. o. I.						
0 - 19%	1.0	3.5	2.5	1.5	2.8	2.1
20 - 39	0	0.7	0		0.4	0.4
Soil depth						
1 - 3	0	1.0	2.5		2.2	2.2
4 - 6	1.0	2.0	0	2.5	1.6	2.1
7 - 9			0	0.5	0	0.4
10 - 12	0					0

Dog violet is a plant of the brown forest soils (Heddle and Ogg 1936, Tansley 1939, Balme 1953 and Mitchell and Jarvis 1956), doing best where no mor layer is present (Gorham 1954) and having a mesophilous (pH 4.8 to 7.0) range (Small 1954).

In the eastern Lammermuirs it is found only on mineral soils with a pH above 3.6 - 4.0 and a relatively shallow upper horizon (see fig. 24). From the soil types on which it grows one may deduce that dog violet probably ranges from free to poor drainage, avoiding only waterlogged and peaty soils.

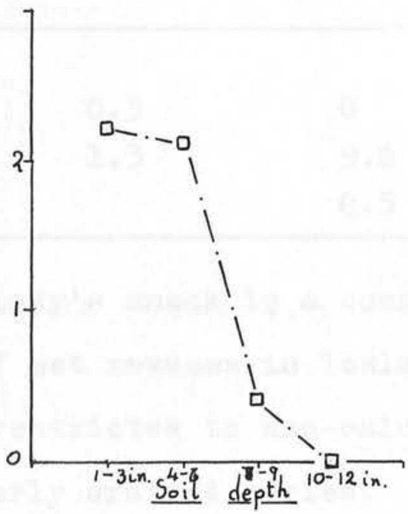


Fig 24
Viola riviniana Soils CDK

Cardamine pratensis

Soil type	Total Frequency	Average Frequency
L	10	2.5
K	6	0.8

	K	L	KL
pH group			
4.6 - 5.0	0	0	0
5.1 - 5.5	0.5	0.5	0.5
5.6 - 6.0	2.0	9.0	4.3

	K	L	KL
L. o. I.			
0 - 19%	0.8		0.8
20 - 39		4.5	4.5
40 - 59		1.0	1.0

	K	L	KL
Soil depth			
4 - 6	0.3	0	0.2
7 - 9	1.3	9.0	2.8
10 - 12		0.5	0.5

Cuckoopint or Lady's smock is a common and conspicuous plant of wet meadows in lowland and upland districts. It is restricted to non-calcareous gleys, particularly the poorly drained series. The table shows that it is probably at the edge of its range of tolerance to soil acidity for there is no record from the 4.6 - 5.0 group and a steep rise to the 5.6 - 6.0 group.

It favours a moderate organic content and the 7 - 9 inch deep group of soils and is absent from the grass peat which covers some of the wetter gleys.

Trifolium repens

Soil type	Total Frequency	Average Frequency
K	42	5.3
L	19	4.8
C	11	2.2
D	6	1.0
J	1	0.04

	J	CD	KL	CDKL
pH group				
3.1 - 3.5	0			
3.6 - 4.0	0	0		0
4.1 - 4.5	0.1	0		0
4.6 - 5.0	0	7.0	0.7	1.3
5.1 - 5.5		10.0	4.8	4.9
5.6 - 6.0			10.0	10.0
L. o. I.				
0 - 19%	0	1.7	5.3	3.7
20 - 39	0.5	1.4	7.0	3.1
40 - 59	0		0	0
60 - 79	0			0
80 - 99	0		5.0	5.0
Soil depth				
1 - 3	0.5	1.2		1.4
4 - 6	0	2.2	2.8	2.5
7 - 9	0	0	7.8	6.5
10 - 12	0		2.5	2.5

Wild white clover has been the subject of intensive study in lowland pastures (Williams 1932, Jones 1933, Blackman 1934) but records of its performance on the uplands, like records of its distribution there, are sparse. Watt (1940) and Balme (1953), working on ranges of dry soils, both found it growing on brown forest or transitional soils but not on podzols or the rendzinas from which the others were derived. Jeffreys (1917) observed that it tended to increase in frequency as soils became wetter, and Milton and Jarvis (1956) confirm this by finding it more on non-calcareous gleys, and less on brown forest soils. They record only a trace from podzols. The table shows the same finding for the eastern Lammermuirs.

In view of its association with the higher ranges of soil reaction (Atkins and Fenton 1930, Ballantyne 1953 and Small 1954) and its positive relationship with soil pH (Fenton 1933, Heddle and Ogg 1933) which is also demonstrated in the table and fig.25 the tendency to grow on moist soils may be due to their usually higher base status than surrounding drier types as described by Glentworth (1944).

The organic matter content of its soils may be of little importance to <u>T. repens</u> but probably it does, as Ballantyne (1953) suggests, prefer a mineral soil. The record for high organic matter content comes from the sedge or grass peat over the gley L, not from <u>Calluna</u>

mor. It is probable that the clover is associated with deeper soils, at least in moders. It is worth noting that the single occurrence in a podzol comes from a moist type in which the upper horizon is both shallow and low in loss on ignition value.

Wild white clover lives in the uplands at one limit of its tolerance to soil conditions. It grows on moist soils of high base status but to determine the individual factors controlling its distribution will form an interesting problem for later study.

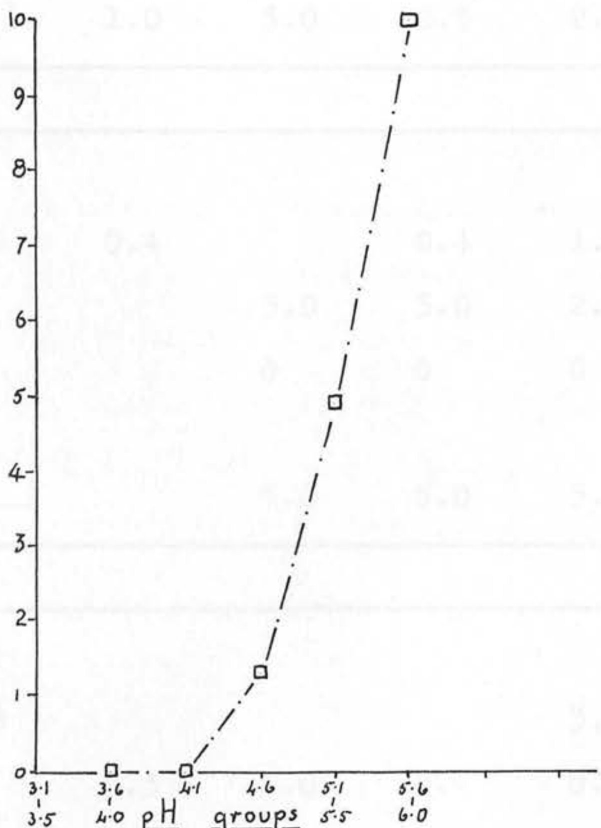


Fig 25

Trifolium repens

□ Soils CDKL

Rumex acetosa

Soil type	Total Frequency	Average Frequency
L	11	2.8
D	15	2.5
K	3	0.4

	D	K	L	KL	DKL
pH group					
4.1 - 4.5	3.3				3.3
4.6 - 5.0	0.5	0.5	1.0	0.7	0.6
5.1 - 5.5	4.0	0	2.5	0.8	1.3
5.6 - 6.0		1.0	5.0	2.3	2.1

	D	K	L	KL	DKL
L. o. I.					
0 - 19%	3.8	0.4		0.4	1.5
20 - 39	0		3.0	3.0	2.5
40 - 59			0	0	0
60 - 79					
80 - 99			5.0	5.0	5.0

	D	K	L	KL	DKL
Soil depth					
1 - 3	3.8				3.8
4 - 6	0	0.3	1.0	0.4	0.3
7 - 9	0	0.5	5.0	1.4	1.2
10 - 12			2.5	2.5	2.5

Common sorrel has been found in rendzinas but not podzols (Watt 1940), and in brown forest soils and incipient podzols but not rendzinas (Balme 1953), and in brown forest soils and non-calcareous gleys but not podzols or peat (Mitchell and Jarvis 1956). This survey finds it on the moist brown forest soil and the two non-calcareous gleys but on no other soils.

Olsen (1925) and Small (1954) agree that its pH range lies between 3.5 and 7.4 and the former showed it to be positively correlated with frequency. The table finds it above 4.1 - 4.5 and suggests a possible positive correlation.

R. acetosa appears on soils of all groups of organic matter content with indications that it might prefer the higher values of the sedge peats. Soils of depth between 1 - 3 and 10 - 12 in. make a habitat for it; a possible positive correlation appears on soils of the KL group.

This is a plant of the moist to wet places which avoids the more acid and the Calluna mor soils.

Erica tetralix

Soil type	Total Frequency	Average Frequency
O	6	1.5
J	24	0.9
P	3	0.2

	P	J	O	PJO
pH group				
3.1 - 3.5		0	2.0	1.3
3.6 - 4.0	0.2	1.6	1.0	0.9
4.1 - 4.5	0	0		0
4.6 - 5.0	0			0
L. o. I.				
0 - 19%		2.0		2.0
20 - 39	0.4	0		0.2
40 - 59	0	0		0
60 - 79	0	0.6		0.38
80 - 99	0	1.1	1.5	1.0
Soil depth				
1 - 3	1.0	0		0.5
4 - 6	0.1	0.9		0.4
7 - 9	0	0.9		0.8
10 - 12		1.0		1.0
13 - 18				0
over 19			2.0	2.0

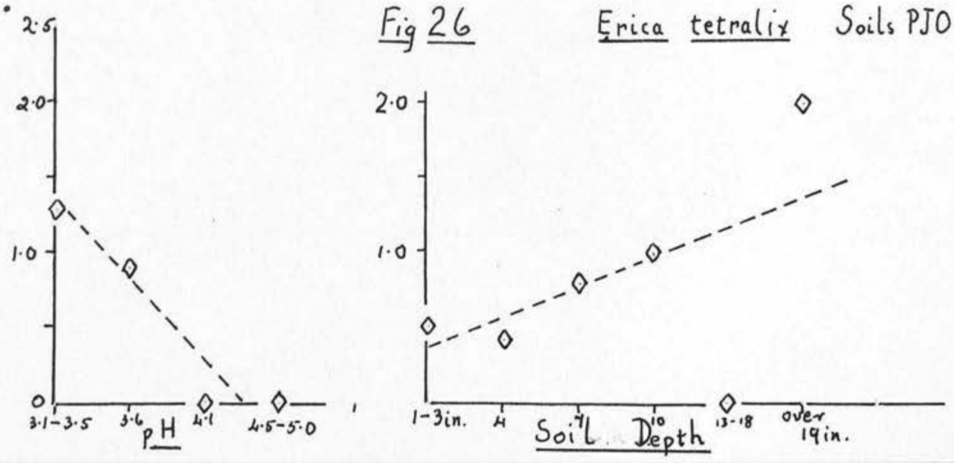
Crossleaved heath is an indicator of moist or wet acid peaty land, in fact of wet podzols (Smith 1904, Smith 1918, Fraser 1940, Gimingham 1949). In Ayrshire it is found on podzols and podzolic gleys only (Mitchell and Jarvis 1956). Here it occurs in low frequencies, confined to peat and the two podzols. The small record from soil P is probably due to the annual summer drought suffered by that soil. Its absence from the podzolic gley is probably due to its preference for a stable even if comparatively low water table rather than a fluctuating one (Rutter 1955).

Small (1954) places it in the "acid tolerant b" group, indicating a range of from below pH 4.8 to between pH 5.5 and 7.0. Ballantyne (1953) gives its range as pH 3.6 to 3.9 and here, where it has the opportunity to range from pH 3.1 - 3.5 to pH 4.6 - 5.0, it is confined to soils with pH below 4.0.

It seems here indifferent to the proportion of mineral to organic matter in the soil.

Both Smith (1904) and Ballantyne (1953) report that E. tetralix shows a preference for the deeper peats and this is confirmed by the data in the table and fig. 26.

Fig 26 *Erica tetralix* Soils PJO ◇



Erica cinerea

Soil type	Total Frequency	Average Frequency
S	15	3.8
P	11	0.6
D	1	0.2
J	1	0.1

	S	D	P	J	SDPJ
pH group					
3.1 - 3.5				0	0
3.6 - 4.0			0.1	0	0.3
4.1 - 4.5	1.5	0.3	3.3	0.1	0.6
4.6 - 5.0	0	0		0	0
5.1 - 5.5	12.0	0			1.3
5.6 - 6.0					

	S	D	P	J	SDPJ
L. o. I.					
0 - 19%	12.0	0.3		0	2.2
20 - 39	1.0	0	2.0	0	1.1
40 - 59			0.5	1.0	0.7
60 - 79			0	0	0
80 - 99			0	0	0

	S	D	P	J	SDPJ
Soil depth					
1 - 3	0	0.3	0	0	0.1
4 - 6	12.0	0	0.8	0.1	0.9
7 - 9		0	0	0	0
10 - 12				0	0

Bell Heather is a plant of the screes and rocky ledges, the steep dry slopes and dry heaths (Smith 1916, Fraser 1940). Small (1954) places it in his acid tolerant b group.

The commonest kind of site for this plant in the eastern Lammermuirs is a scree or a shallow podzol on a steep slope. It is not confined to the most acid soils but spreads over from 3.6 - 4.0 to 5.1 - 5.5. The table shows the plant growing on shallow mineral soils (see fig. 27).

This species contrasts markedly with E. tetralix in its ecological amplitude, the latter acidiphilous and moisture-loving, the former with a wider pH range and intolerant of high moisture contents in its soils. Both can be used as indicators of soil and site characters in this area.

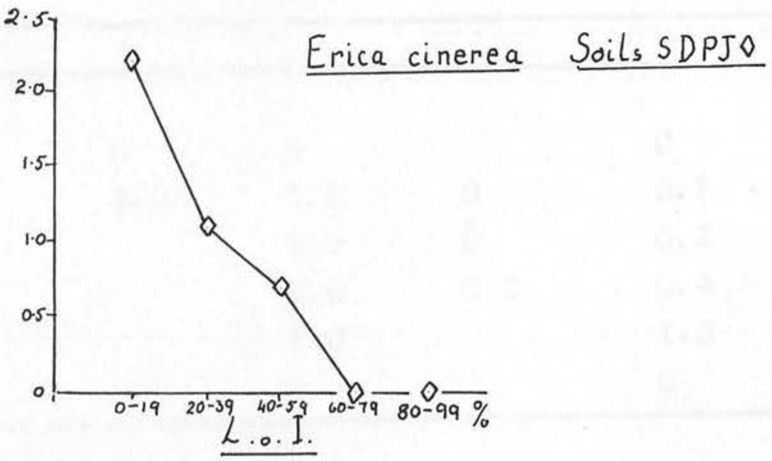


Fig. 27

Empetrum nigrum

Soil type	Total Frequency	Average Frequency
C	8	1.6
J	17	0.6
O	1	0.3
P	2	0.1
M	1	0.1

	C	PJO	M	Total
pH group				
3.1 - 3.5		0.7		0.7
3.6 - 4.0	0	0.1	0	0.1
4.1 - 4.5	0	1.0	0.2	0.7
4.6 - 5.0	1.5	1.0		1.3
5.1 - 5.5	5.0			5.0
L. o. I.				
0 - 19%	2.5	0		1.7
20 - 39	1.0	0.1		0.4
40 - 59		0		0
60 - 79		0.3		0.2
80 - 99		0.7		0.7
Soil depth				
1 - 3	0	0		0
4 - 6	2.0	0.6	0	0.7
7 - 9		0.2	0	0.2
10 - 12		1.0	0.2	0.4
13 - 18		1.0		1.0
over 19		0		0

The crowberry is never a common or abundant plant, being local in its distribution. Smith (1916) says it is most frequently found on peaty ground but also appears on "hard" land, that is, on dry mineral soils. Mitchell and Jarvis (1956) record it only from podzols. In the eastern Lammermuirs it occurs most frequently on the dry brown forest soil and also occasionally on each member of the podzolic group.

Although Small (1954) classifies it as acidiphilous its range here is from 3.1 - 3.5 to 5.1 - 5.5 and there is a suggestion that it prefers the upper end to the lower. The topsoils vary from moder to mor, from low to high organic matter content and in depth from 4 - 6 inches to 13 - 18 inches. There may be an association with more mineral soils in the brown forest soil (type C).

Cirsium palustre

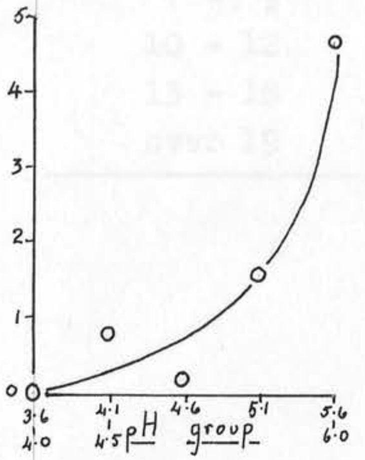
Soil type	Total Frequency	Average Frequency
L	12	3.0
K	15	1.9
C	2	0.4
D	2	0.3

	CD	KL	CDKL
pH group			
3.6 - 4.0	0		0
4.1 - 4.5	0.8		0.8
4.6 - 5.0	0.3	0	0.2
5.1 - 5.5	0	2.2	1.6
5.6 - 6.0		4.7	4.7
L. o. I.			
0 - 19%	0.7	1.9	1.4
20 - 39	0	4.0	1.1
40 - 59		1.0	1.0
60 - 79			
80 - 99		3.0	3.0
Soil depth			
1 - 3	0		0
4 - 6	0.8	1.0	0.9
7 - 9	0	3.6	3.0
10 - 12		2.0	2.0

Marsh thistle is a prominent constituent of wet meadows (Tansley 1939), poorly drained soils, especially "flushes" and non-calcareous gleys (Fraser 1936). Mitchell and Jarvis (1956) report it mostly from the latter soils and a little from cultivated podzolic gleys. In this upland region it grows almost exclusively on the two non-calcareous gleys (K and L). Low average frequencies have been recorded from the brown forest soils.

In relation to acidity the range follows the trend described by Olsen (1925) who set limits at pH 5.0 and pH 7.4 with an optimum at pH 6.0 to 6.5. The table and fig. 28 show a rise, from pH 4.1 - 4.5 to pH 5.6 - 6.0, which is steep in the last two groups.

Cirsium palustre occurs on soils which cover the whole range of values for loss on ignition, but only on moders or grass-peat, never mor or Eriophorum peat. From the table and fig. 28 there seems to be a clear correlation between the deeper soils and higher average freqencies.



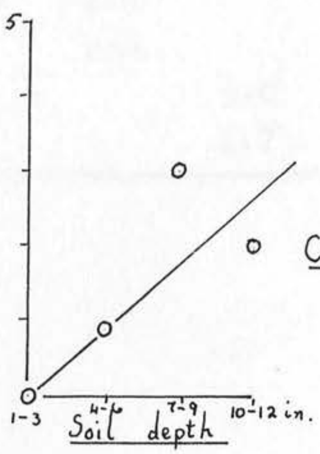


Fig 28

Cirsium palustre. o = Soils CDKL

Trichophorum caespitosum

Soil type	Total Frequency	Average Frequency
J	68	2.4
M	15	1.7
O	5	1.3
P	16	0.9

pH group	P	J	O	M	PJOM
3.1 - 3.5		3.0	1.5		2.0
3.6 - 4.0	0.9	3.9	1.0	3.75	2.5
4.1 - 4.5	0.7	0.7			0.5
4.6 - 5.0		0			0

L. o. I.	P	J	O	M	PJOM
0 - 19%		5.0			5.0
20 - 39	0.8	0			0.6
40 - 59	0.5	0		0	0.3
60 - 79	0.3	3.3		1.0	2.1
80 - 99	1.8	2.1	1.3	2.3	2.0

Soil depth	P	J	O	M	PJOM
1 - 3	1.0	0.5			0.8
4 - 6	0.9	2.2		0	1.4
7 - 9	1.0	2.8		5.0	2.9
10 - 12		3.5		0	1.0
13 - 18			3.0		3.0
over 19			1.7		1.7

Deer hair grass is a plant of peaty soils. It is dominant or abundant on the blanket bogs of western Scotland (Fraser and Robertson 1935, Fraser 1940), being generally found associated with a peat less spongy and less well drained than that on which Eriophorum grows (Smith 1916). This is the pseudo-fibrous peat of Fraser (1933). It is never important in eastern Scotland but a minor species of moist podzols and peats.

The range of soil pH values shown in the table is the same as those given by Fraser (1933), 3.0 to 4.4, and Ballantyne (1953), 3.6 to 4.3. It is a truly acidiphilous species.

If the 0 - 19% group in soil J is disregarded, for the figure is derived from a single record, there may well be a positive correlation between frequency and loss on ignition. Certainly in soils P and M this is apparent. Examination of the values for depth of the mor horizon shows a possible association with deeper soils (see fig. 29).

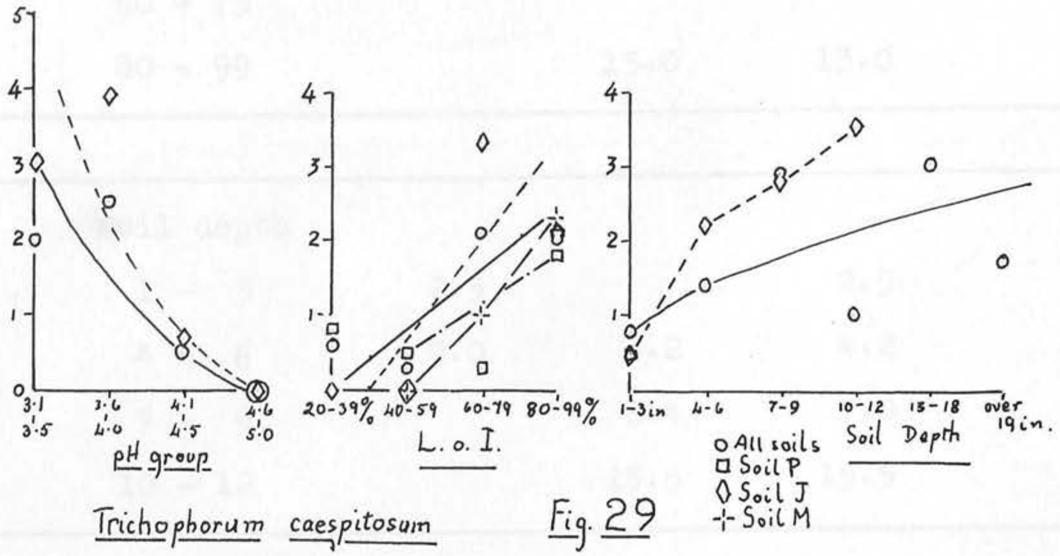


Fig. 29

Holcus lanatus

Soil type	Total Frequency	Average Frequency
L	34	8.5
K	55	6.9
D	19	3.7

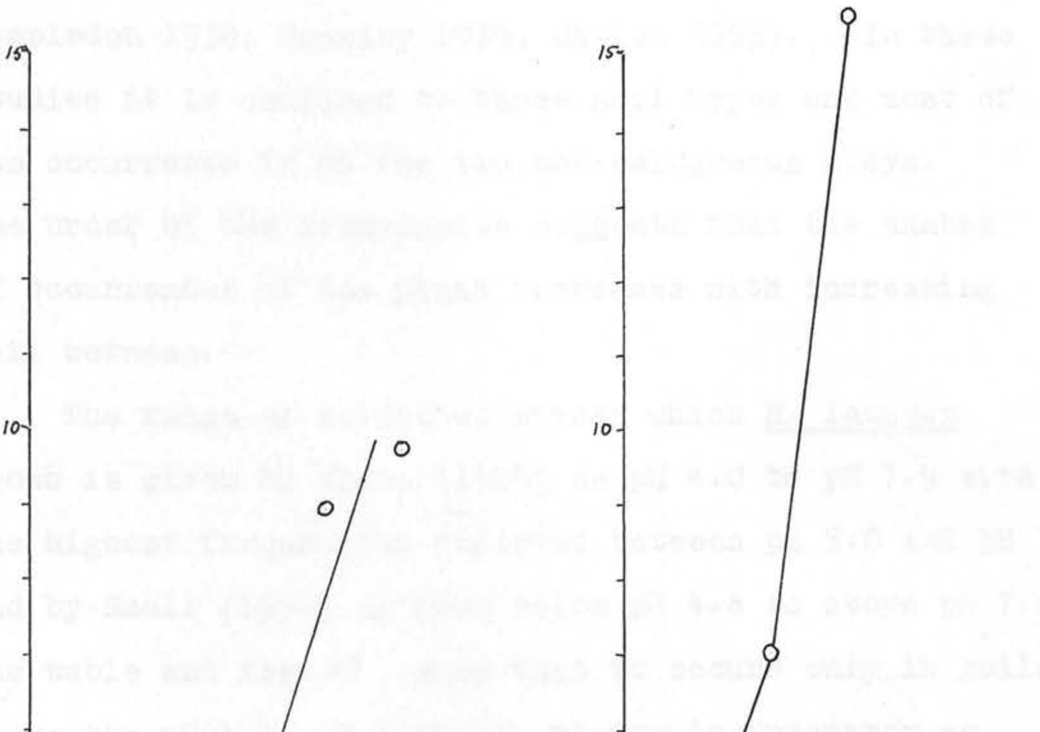
	D	KL	DKL
pH group			
4.1 - 4.5	4.6		4.6
4.6 - 5.0	2.5	1.3	1.8
5.1 - 5.5	0	10.3	8.9
5.6 - 6.0		9.7	9.7

	D	KL	DKL
L. o. I.			
0 - 19%	2.5	6.9	5.4
20 - 39	4.5	1.5	3.0
40 - 59		18.0	18.0
60 - 79			
80 - 99		13.0	13.0

	D	KL	DKL
Soil depth			
1 - 3	2.5		2.5
4 - 6	9.0	3.2	4.2
7 - 9		8.4	7.0
10 - 12		15.5	15.5

Fig 30

Holcus lanatus



o = Soils DKL

Yorkshire fog, although regarded as a weed in the cultivated lowlands, is valued for the grazing it affords on the hill, where it is associated with the moister, deeper, more fertile soils (Jeffreys 1917, Stapledon 1936, Tansley 1939, Davies 1952). In these studies it is confined to three soil types and most of its occurrence is on the two non-calcareous gleys. The order of the frequencies suggests that the number of occurrences of the plant increases with increasing soil wetness.

The range of acidities within which H. lanatus grows is given by Olsen (1925) as pH 4.0 to pH 7.9 with the highest frequencies observed between pH 5.0 and pH 7.4, and by Small (1954) as from below pH 4.8 to above pH 7.0. The table and fig. 30 show that it occurs only in soils above the pH 4.1 - 4.5 group, rising in frequency as the values do.

It is probably indifferent to the amount of combustible material in the soil, but is always on moder or grass peat, never on Calluna mor. There is a clear relationship with soil depth (fig. 30).

This is a grass of the "better" soils, especially when they are wet.

Holcus mollis

Soil type	Total Frequency	Average Frequency
C	15	3.0
D	3	0.5
L	1	0.3
K	1	0.1

	CD	KL	CDKL
pH group			
3.6 - 4.0	15.0		15.0
4.1 - 4.5	0.8	0	0.8
4.6 - 5.0	0	0.7	0.3
5.1 - 5.5	0	0	0
L. o. I.			
0 - 19%	0.5	0.1	0.3
20 - 39	3.0	0.5	2.3
40 - 59		0	0
60 - 79			
80 - 99		0	0
Soil depth			
1 - 3	3.6		3.6
4 - 6	0	0.4	0.2
7 - 9	0	0	0
10 - 12		0	0

Creeping softgrass has been described in the Biological Flora by Ovington and Scurfield (1956) as a plant of well drained light loams with a low summer water table and a shallow humus layer, rich in bases and with a pH between 3.8 and 5.3. Mitchell and Jarvis (1956) record it from two non-calcareous and one podzolic gley soils, the latter a cultivated soil, and from brown forest soil only in woodland. This survey has found it mostly in the dry brown forest soil, partly in woodland and in very low frequencies from three wetter soils, a tendency opposite to that shown by H. lanatus.

Fenton (1948) mentions creeping softgrass as a common weed of light acid arable land. Its pH range is given as 5.4 to 7.2 (Atkins and Fenton 1930), and as 4.5 to 5.7 (Ballantyne) while Jowett and Scurfield (1949b) found it was positively related to soil pH between 3.3 and 4.9. The table shows a negative relation between frequency and pH between 3.6 and 5.5.

The data shown in the table confirms the statement that H. mollis inhabits most often soils low in organic matter (Ballantyne 1953, and Ovington et al., op. cit.), and with shallow A horizons (Gorham 1954).

Agrostis stolonifera

Soil type	Total Frequency	Average Frequency
K	35	4.4
L	18	4.5

	K	L	KL
pH group			
4.6 - 5.0	5.5	5.0	5.3
5.1 - 5.5	2.25	7.5	3.7
5.6 - 6.0	7.5	0	5.0
L. o. I.			
0 - 19%	4.4		4.4
20 - 39		2.5	2.5
40 - 59		0	0
60 - 79			
80 - 99		13.0	13.0
Soil depth			
1 - 3			
4 - 6	3.0	5.0	3.4
7 - 9	5.75	0	4.6
10 - 12		7.5	7.5

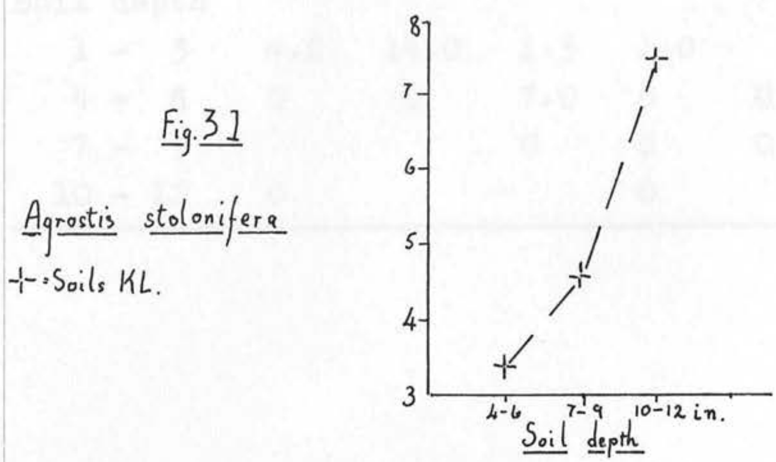
Fiorin or creeping bent is not common on these hills. It is known to prefer moister and more fertile soils than do A. tenuis or A. canina and to flourish on clay soils (Jeffreys 1917, Tansley 1939). Mitchell and Jarvis (1956) recorded it from the moist brown forest soil with only a trace on cultivated podzolic gley. It occurs here only on the two non-calcareous gleys but then in appreciable frequencies. On these soils it is present on all pH groups. Olsen (1925) found it growing over a range of acidities between pH 6.5 - 7.0 and 7.5 - 7.9, rising in frequency as the pH rose.

The grass spans the range of organic matter contents from 0 - 19% to 80 - 99% but only in moder or grass peat, never in mor soils. There is a positive correlation with soil depth between the limits 4 - 6 inches and 10 - 12 inches (see fig.31).

This bent has requirements which limit its spread in hill country. In the eastern Lammermuirs it can satisfy its need for moist, deep soils with a relatively high base status only in the two non-calcareous gleys, neither of which is extensively distributed.

Fig.31

Agrostis stolonifera



Group 4: Plants of low frequency

Oxalis acetosella

Soil type	Total Frequency	Average Frequency
C	14	2.8
D	12	2.0
S	4	1.0
K	1	0.1
J	2	0.1

	S	C	D	J	K	SCDJK	SCD
pH group							
3.1 - 3.5				0		0	0
3.6 - 4.0	0	14.0		0		0.9	14.0
4.1 - 4.5	0	0	3.0	0		0.6	1.5
4.6 - 5.0	4.0	0	0.5	1.0	0	0.9	1.2
5.1 - 5.5		0	2.0		0.3	0.4	0.7
5.6 - 6.0					0	0	0
L. o. I.							
0 - 19%	0	0	1.3	0	0.1	0.4	0.7
20 - 39	1.3	4.7	3.5	1.0		2.7	3.1
40 - 59						0	0
60 - 79						0	0
80 - 99						0	0
Soil depth							
1 - 3	4.0	14.0	1.3	1.0		3.1	3.8
4 - 6	0	0	7.0	0	0.3	0.4	1.2
7 - 9			0	0	0	0	0
10 - 12	0			0		0	0

Woodsorrel is commonly associated with woodlands and brown forest soils, but has also been recorded from non-calcareous gleys (Mitchell and Jarvis 1956).

In this survey it appears in low frequencies on the brown forest and scree soils and as traces in the gley K and the podzol J. It spans a range of soil acidity from pH 3.6 - 4.0 to 5.1 - 5.5 but could possibly appear on even higher groups as Small (1954) includes it amongst his amphitolerant species. In all soils, even the podzol, it is confined to those in which the loss on ignition is below 39% and the depth not more than six inches.

This small herb of the well drained less acid soils is closely associated with conditions of shade, in fact it is almost invariably found in woodland, under bracken or in a dense growth of grass.

Veronica officinalis

Soil type	Total Frequency	Average Frequency
S	4	1.0
K	8	1.0
C	2	0.4
D	2	0.3

pH group	SCDK	L.o.I.	SCDK	Soil depth	SCDK
3.6 - 4.0	0	0 - 19	0.2	1 - 3	0.3
4.1 - 4.5	0.3	20 - 39	0.7	4 - 6	1.1
4.6 - 5.0	0.6			7 - 9	0.4
5.1 - 5.5	1.0			10 - 12	1.0

Common speedwell is characteristic of dry poor soils (Tansley 1939, Fraser 1940). Watt (1940) reported it from leached rendzinas only and Balme (1953) from these and brown forest soils. In Ayrshire it is listed as occurring on moist brown forest soils or the poorly drained non-calcareous gley and, rarely, on cultivated podzolic gleys (Mitchell and Jarvis 1956). This minor plant of hill grassland is recorded here from the screes, both brown forest soils and the gley K.

Watt (1940) and Balme (1953) both found it on soils of relatively high pH, the former at 7.8 and the latter between 5.8 and 7.6. Here it runs from 4.1 - 4.5 to 5.1 - 5.5 with a suggestion of a positive trend. (fig.). All the soils are comparatively low in organic matter content. Up to 12 inches, depth is not a limiting factor.

<u>Thymus drucei</u>

Soil type	Total Frequency	Average Frequency
C	11	2.2
S	2	0.5
K	4	0.5

	S	C	K	SCK
pH group				
3.6 - 4.0		0		0
4.1 - 4.5	1.0	0		0.7
4.6 - 5.0	0	2.5	0	1.3
5.1 - 5.5	0	6.0	0.7	1.5
5.6 - 6.0			0	0
L. o. I.				
0 - 19%	0	3.0	0.5	0.9
20 - 39	0.7	1.7		1.2
Soil depth				
1 - 3	0	0		0
4 - 6	0	2.8	1.0	1.7
7 - 9			0	0
10 - 12	2.0			2.0

Wild thyme has featured in a Biological Flora by Piggot (1955). He wrote that it most frequently grows on skeletal soils, rendzinas, shallow brown earths and thin podzols, all likely to suffer summer drought. He also noted that it is found in silty clay soils by the margins of base rich flushes and river gravels subject to winter flooding. Here, it has been seen mostly on the freely drained brown forest soil. However, it also occurs over screes and the gley K. This latter soil has a fluctuating water table and, most often, a heavy subsoil.

The pH range is given as 4.5 to 8.0 and a preference for the high values indicated, but it is here found at the lower end of the range.

The topsoil inhabitted by T. drucei is said to be composed of a "mull" humus, but values for loss on ignition as high as 80% have been recorded. This, however, was on "brown peat" over limestone. The figures recorded here are all below 40%.

Teucrium scorodonia

Soil type	Total Frequency	Average Frequency
S	11	2.8
D	1	0.2

	S	D	SD
pH group			
3.6 - 4.0		0	0
4.1 - 4.5	1.5	0.3	0.8
4.6 - 5.0	8.0	0	2.7
5.1 - 5.5	0	0	0

	S	D	SD
L. o. I.			
0 - 19%	0	0.3	0.2
20 - 39	3.7	0	2.2

	S	D	SD
Soil depth			
1 - 3	8.0	0.3	1.8
4 - 6	0	0	0

This herb is regarded in southern Scotland as a plant of screes (Fenton 1939) where it plays an important part in fixing the loose material. It is also a part of the ground flora of woodlands on soils of low base status (Tansley 1939). This survey recorded it from the soil S mostly and once from a brown earth in woodland. The pH values lie between 4.1 and 5.0 and the soils are both shallow and mineral.

Campanula rotundifolia

Soil type	Total Frequency	Average Frequency
D	5	0.8
S	3	0.8
C	2	0.4

	S	CD	SCD
pH group			
3.6 - 4.0		1.0	1.0
4.1 - 4.5	1.5	0.5	0.8
4.6 - 5.0	0	0.8	0.6
5.1 - 5.5	0	0.5	0.3

	S	CD	SCD
L. o. I.			
0 - 9%	0	0.8	0.7
10 - 19	1.0	0.4	0.6

	S	CD	SCD
Soil depth			
1 - 3	0	1.2	1.2
4 - 6	0	0.2	0.2
7 - 9		0	0
10 - 12	2.0		2.0

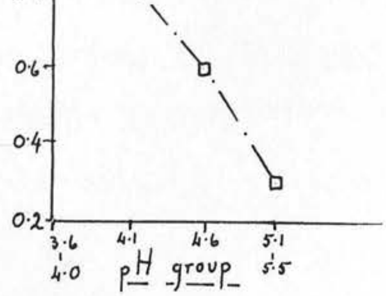
Bluebell appears in low frequencies and only on a certain group of soils, the brown forest and the screes. This is in conflict with the findings of Balme (1953) who considered the species indifferent to soil type within a range from rendzina through brown forest to podzol but is partly in accord with the findings of Watt (1940) when he reports on its appearance upon the transition between brown forest and podzol to either of these types.

Small (1954) places Campanula rotundifolia among the alkatolerant group, which means its pH range runs from above 4.8 to between 7.0 and 7.9, but it has been found on soils which range from 3.8 to 8.2 by Watt (1940) and 4.2 to 7.0 by Balme (1953). The table displays values between 3.6 - 4.0 and 5.1 - 5.5 and there is a tendency for the frequencies to fall as the pH rises, (fig. 32).

Growing only on the brown forest soils and screes it is necessarily confined to "mineral" soils. The frequencies returned from the brown forest soil are highest in the shallowest group but that from the scree comes from the deepest example.

Fig. 32

Campanula rotundifolia
□ Soils S.C.D.



Achillea millefolium

Soil type	Total Frequency	Average Frequency
D	6	1.0
K	3	0.4

pH group	DK	L. o. I.	DK	Soil Depth	DK
4.1 - 4.5	0.3	0 - 19%	0.8	1 - 3	1.5
4.6 - 5.0	0	20 - 39%	0	4 - 6	0.6
5.1 - 5.5	1.6			7 - 9	0

Yarrow is a common plant of natural grasslands, often associated with light dry soils (Tansley 1939). It is recorded on brown forest soils only in uplands (Balme 1953, Mitchell and Jarvis 1956). Here it is a minor plant of the communities on moist brown forest soil and the non-calcareous gley of poor drainage.

Olsen (1925) records it only on a soil with a pH of 6.8 and Small (1954) includes it in the amphitolerant group. The table shows the herb to occur among the moderately acid shallow and mineral soils.

Plantago lanceolata

Soil type	Total Frequency	Average Frequency
C	7	1.4
K	4	0.5
S	1	0.3

pH group	SCK	L. o. I.	SCK	Soil depth	SCK
3.6 - 4.0	0	0 - 19%	0.6	1 - 3	0
4.1 - 4.5	0.3	20 - 39	0.8	4 - 6	1.2
4.6 - 5.0	0.8			7 - 9	0
5.1 - 5.5	1.2			10 - 12	1.0
5.6 - 6.0	0				

Ribwort plantain is common in the lowlands, and has been recorded over skeletal chalk and limestone, on sand dunes, from brown forest soils and from the equivalent of soil K (Watt 1940, Balme 1953, Gimingham and Robertson 19 , Mitchell and Jarvis 1957). Olsen (1925) gives the pH range it inhabits as 4.5 to 7.9 with an optimum at 6.0 - 6.9, and Balme (1953) found it between 4.6 and 7.6.

It is seen to be confined to mineral soils varying in drainage from the driest to the poorly drained type with a fluctuating water table.

Eriophorum angustifolium

Soil type	Total Frequency	Average Frequency
O	7	1.8
J	1	0.04

	J	O	JO
pH group			
3.1 - 3.5	0	0.5	0.3
3.6 - 4.0	0.1	3.0	0.4
4.1 - 4.5	0		0
4.6 - 5.0	0		0

L. o. I.			
20 - 39%	0		0
40 - 59	0		0
60 - 79	0		0
80 - 99	0.1	1.8	0.5

Soil depth			
7 - 9	0.1		0.1
10 - 12			0
13 - 18		1.0	1.0
over 19		2.0	2.0

This close relative of the Drawmoss is a plant of the wet podzols and fens. It can tolerate a wide range of soil acidities, from pH 3.5 to 7.0 and grows on soils with organic matter contents ranging from 10% to 90% (Phillips 1954).

It is infrequent in East Lothian, and, where found, is almost invariably on deep wet peat with a pH value below 4.0 and a high content of combustible material.

Poa pratensis

Soil type	Total Frequency	Average Frequency
L	4	1.0
D	4	0.7
K	5	0.6
C	2	0.4

pH group	CDKL	L. o. I.	CDKL	Soil depth	CDKL
3.6 - 4.0	0	0 - 19%	0.6	1 - 3	0.6
4.1 - 4.5	0	20 - 39	0.4	4 - 6	0.4
4.6 - 5.0	1.1	40 - 59	0	7 - 9	0.7
5.1 - 5.5	0.5	60 - 79		10 - 12	2.0
5.6 - 6.0	1.0	80 - 99	4.0		

Smooth-stalked meadow-grass is usually regarded as an inhabitant of lowland meadows (Tansley 1939) and of the lighter and drier soils below cultivated grassland (Moore 1949). On hill and marginal land it is recognised as an indicator of "better" soils, the brown forest and non-calcareous gleys (Mitchell and Jarvis 1956). Here it is an uncommon plant and confined to these soils.

Olsen (1925) found it only on soils with a pH value over 5.0 and it increased in frequency as the value rose to 7.0 - 7.4. It has, however, been recorded from soils with figures as low as pH 3.8 (Watt 1940) and 4.6 (Ballantyne 1953). Heddle and Ogg (1933) obtained an increase in its abundance by flushing a heathy sward which raised the pH of the soil from 4.6 to 6.0. It is at the lower limit of its pH range in the Lammermuirs.

Contrary to the findings of Ballantyne (1953), who considered it to be confined to "mineral" soils, P. pratensis is shown here to grow also on the "organic" soils of grass peat over gley.

Deschampsia caespitosa

Soil type	Total Frequency	Average Frequency
K	10	1.3
M	1	0.1

pH group	K	M	L. o. I.	K	M	Soil depth	K	M
3.6 - 4.0		0.3	0 - 19%	1.3		4 - 6	0.50	0
4.1 - 4.5		0	20 - 39			7 - 9	2.00	0
4.6 - 5.0	0		40 - 59		1.0	10 - 12		0.2
5.1 - 5.5	2.5		60 - 79		0			

Tufted hair grass is an inhabitant of wet meadow soils (Fraser 1940), mineral flush soils (Pearsall 1950) and non-calcareous gleys (Mitchell and Jarvis 1956). It dominates certain types of grassland where it often forms big tussocks. In the eastern Lammermuirs this is rare and where the grass occurs it is usually as a small cluster of shoots or a single steckling amongst other grasses. The soils from which records of this plant were obtained are poorly drained series but the podzolic gley registers only a trace.

The pH range has been given by various writers as 5.0 - 5.5 to 7.5 - 7.9 with an optimum about 5.5 - 6.4 (Olsen 1925), 6.0 to 6.5 - (Atkins and Fenton 1930) and 4.9 to 5.7 (Ballantyne 1953). Here it is recorded in the low 3.6 - 4.0 group in a very small average frequency. Its association with mineral soils is reflected in the tables.

Group 5: The mosses

Polytrichum commune

Soil type	Total Frequency	Average Frequency
M	60	6·7
K	15	1·9
J	27	1·0
L	1	0.3
O	1	0.3

	J	O	M	K	L	Total
pH group						
3.1 - 3.5	0	0.5				0.3
3.6 - 4.0	0.1	0	1.0			0.3
4.1 - 4.5	0.7		11.6			4.3
4.6 - 5.0	9.0			7.0	1.0	6.6
5.1 - 5.5				0.3	0	0.2
5.6 - 6.0				0	0	0
L. o. I.						
0 - 19%	0			1.9		1.7
20 - 39	3.5				0.5	2.0
40 - 59	0		0		0	0
60 - 79	0.2		0			0.2
80 - 99	1.3	0.3	7.4		0	2.5
Soil depth						
1 - 3	3.5					3.5
4 - 6	1.8		6.0	3.3	1.0	2.4
7 - 9	0		6.7	0.3	0	1.0
10 - 12	0		6.8		0	3.8
13 - 18		1.0				1.0
over 19		0				0

Deer moss is usually associated with the acid peats or Calluna mor of wet moorlands (Grebe 1918, Tansley 1939, Watson 1955) but Mitchell and Jarvis (1956) record if from brown forest soils and podzolic gleys in addition to peat and two podzols. The highest average frequency recorded here is on the podzolic gley, in a value greater than that found for all the other soil types together. Much lower come the poorly drained non-calcareous gley followed by the podzol J. The two wettest soils in the area have the lowest figures. This suggests an association with a high but fluctuating water table rather than with a peaty topsoil, and in support of this may be added the apparent indifference of this plant to such factors as loss on ignition and depth of topsoil. This does not conflict with the view put forward by McVean (1952) that Polytrichum commune displaces Molinia when a fluctuating water table becomes high and stable due to lack of drainage. It suggests that the drainage is not as good as it might be, a fact which can be confirmed by inspecting the open drains on the area and by the figures given for Molinia which are low for a soil particularly suited to its growth.

Montgomery (1931) gives the soils the moss occurs on a pH range from 4.2 to 7.6 with maximum frequencies at 5.0 to 5.6. Here it ranges from 3.1 - 3.5 to 5.1 - 5.5 with an optimum between 4.1 and 5.0.

Polytrichum juniperinum

Soil type	Total Frequency	Average Frequency
D	3	0.5
S	1	0.3
P	3	0.2
M	1	0.1

pH group		L. o. I.		Soil depth	
3.6 - 4.0	0.2	0 - 19%	0.8	1 - 3	0.6
4.1 - 4.5	0	20 - 39	0.2	4 - 6	0.1
4.6 - 5.0	0	40 - 59	0	7 - 9	0.3
5.1 - 6.0	2.0	60 - 79	0.3	10 - 12	0
		80 - 99	0.1		

This moss, a common inhabitant of acid heaths and Calluneta over humus turf (Grebe 1918, Watson 1955), is often associated with drier and more mineral soils (Tansley 1939). It appears here mostly on drier mineral soils but does extend in very low frequencies into peaty and moist soils. The pH values recorded come at the lower end of the range given by Watt (1940) which runs from 3.7 to 7.8.

Dicranum scoparius

Soil type	Total Frequency	Average Frequency
S	4	1.0
C	3	0.6
P	7	0.4
M	2	0.2
D	1	0.2
J	1	0.04

pH group		L. o. I.		Soil depth	
3.1 - 3.5	0	0 - 19%	0	1 - 3	0.1
3.6 - 4.0	0.2	20 - 39	0.6	4 - 6	0.4
4.1 - 4.5	0.3	30 - 59	0	7 - 9	0
4.6 - 5.0	0.4	50 - 79	0.06	10 - 12	0.8
5.1 - 5.5	0	80 - 99	0.3		

Some references to this moss associate it with Calluna mor (Grebe 1918 and Watt 1940). On the other hand Balme (1953) maintains that within a freely drained group ranging from rendzina to podzol it is indifferent to soil type and Mitchell and Jarvis (1956) recorded it from brown forest soils and very poorly drained gleys mainly and only in very low frequencies from podzolic soils. The soils it inhabits here range from the screes through brown forest to podzols: the drier types come first.

It has been found on soils with pH values ranging from 3.8 to 7.2 (Montgomery 1931, Watt 1940, Balme 1953) but here only between 3.6 and 5.0.

<u>Hypnum cupressiforme</u>

Soil type	Total Frequency	Average Frequency
J	47	1.7
M	7	0.8
P	13	0.7
C	3	0.6
S	1	0.3

pH group		L. o. I.		Soil depth	
3.1 - 3.5	0	0 - 19%	2.3	1 - 3	1.3
3.6 - 4.0	0.8	20 - 39	0.8	4 - 6	1.1
4.1 - 4.5	1.9	40 - 59	0	7 - 9	0.9
4.6 - 5.0	0.6	60 - 79	0.8	10 - 12	1.6
5.1 - 5.5	0.5	80 - 99	1.5		

This common moss is said to be indifferent to soil type (Watt 1940, Balme 1953, Mitchell and Jarvis 1956). On the other hand Fraser (1940) names it as a plant of dry heaths and Watson (1955) finds its normal habitat in grassy heaths and upland woods.

In the Lammermuirs it appears only on the screes, the dry brown forest soil, the dry podzol and the two moist to wet podzolic soils. The soil reaction group in which the plant lives runs from pH 3.6 - 4.0 to 5.1 - 5.5 with a maximum frequency at 4.1 - 4.5. It is indifferent to the factors of loss on ignition and soil depth.

The inference which may be drawn from the tables is that this moss grows on the drier acid soils.

<u>Pleurozium schreberi</u>

Soil type	Total Frequency	Average Frequency
C	10	2.0
K	11	1.4
S	2	0.5
M	4	0.4
D	2	0.3
J	7	0.3
O	1	0.3
P	4	0.2
L	-	-

pH group	S	CD	PJO	M	K	Total
3.1 - 3.5			0			0
3.6 - 4.0		0	0.1	0		0.1
4.1 - 4.5	1	0	0.5	0.8		0.5
4.6 - 5.0	0	2.3	0		3.0	1.7
5.1 - 5.5	0	1.5			1.3	1.1
5.6 - 6.0					0	0

L. o. I.	S	CD	PJO	M	K	Total
0 - 19%	0	0.7	0		1.4	0.9
20 - 39	0.7	1.1	0.7			1.0
40 - 59			0	0		0
60 - 79			0.4	0		0.4
80 - 99			0.1	0.7		0.2

Soil depth	S	CD	PJO	M	K	Total
1 - 3	0	0.4	1.3			0.7
4 - 6	0	2.0	2.4	2.0	1.5	0.7
7 - 9		0	0.1	0.3	1.3	0.3
10 - 12	2.0		0	0.2		0.4
13 - 18			0			0
over 19			0.3			0.3

Listed as a denizen of raw humus soils (Grebe 1918) and of wet heaths (Fraser 1940), this moss was found by Balme (1953) both on brown forest soils and podzols but never on rendzinas. Here it grows on every soil type except soil L which is not only the wettest of the mineral soils but has the highest pH range of all. The dry brown forest soil and the poorly drained gley return the highest frequencies, other soils following well behind.

The assertion that P. schreberi is a moss of acid soils, a strong calcifuge (Watson 1955), is borne out by the data on the table and fig. 33 which show it to have a narrow range from 3.6 - 4.0 to 5.1 - 5.5 with an optimum at 4.6 - 5.0.

There appears to be an association with mineral soils. It is difficult to see how soil depth can affect a plant whose rhizoids penetrate the soil by less than half an inch. In a study of this type where the pH and loss on ignition figures are based on a sample taken from a horizon which may vary from one to over nineteen inches deep the actual layer in which the rhizoids live may be missed out entirely.

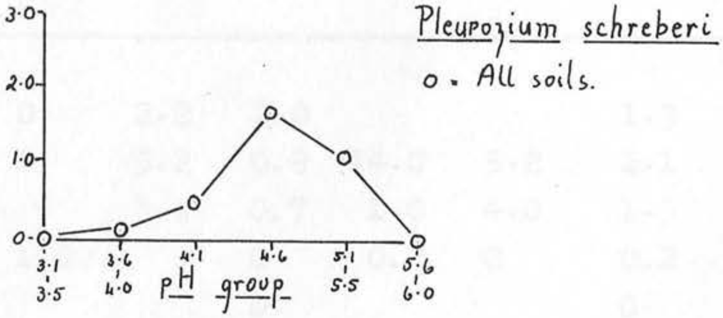


Fig. 33

Rhytidiadelphus squarrosus

Soil type	Total Frequency	Average Frequency
D	26	4.3
K	32	4.0
L	14	3.5
M	18	2.0
J	26	0.9
C	4	0.8
O	1	0.3
S	1	0.3
P	2	0.1

	S	CD	PJO	M	KL	Total
pH group						
3.1 - 3.5			0			0
3.6 - 4.0		0	0.1	0		0.1
4.1 - 4.5	0.5	3.0	2.2	3.6		2.5
4.6 - 5.0	0	2.0	0		4.7	2.2
5.1 - 5.5	0	5.0			2.5	2.8
5.6 - 6.0					5.0	5.0

	S	CD	PJO	M	KL	Total
L. o. I.						
0 - 19%	0	2.0	0		4.0	2.2
20 - 39	0.3	3.6	1.7		7.0	2.2
40 - 59			0.7	0	0	0.4
60 - 79			0.2	0		0.2
80 - 99			0.5	2.8	0	1.0

	S	CD	PJO	M	KL	Total
Soil depth						
1 - 3	0	2.2	2.0			1.9
4 - 6	0	3.2	0.9	14.0	5.2	2.1
7 - 9		3.0	0.7	1.0	4.0	1.5
10 - 12	1.0		0	0.2	0	0.2
13 - 18			0			0
over 19			0.3			0.3

This moss is described by Grebe (1918) as a colonist of raw humus soils but has been found by both Watt (1940) and Balme (1953) to inhabit rendzina and brown forest soils and never podzols. In the records from the Ayrshire soil survey it appears mainly on brown forest and gley soils and only rarely on podzolic types. It is here found in moderate frequencies on the moist brown forest soil and the two non-calcareous gleys followed by the podzolic gley. The podzols, peat and the scree come behind with very low figures.

Although Watson (1955) states that it is indifferent to soil reaction there is a positive relationship above pH 3.6 - 4.0. It has its highest frequency on the 20 - 39% loss on ignition group and the shallower topsoils.(fig.).

Moist to wet mineral soils, not of the most acid type, are favoured by this species. This may be a reflection of its association with grassy vegetation which most often grows on such soils.

Hylocomium splendens

Soil type	Total Frequency	Average Frequency
S	12	3.0
K	23	2.9
M	24	2.7
C	6	1.2
D	5	0.8
J	23	0.8
O	2	0.5
P	5	0.3
L	-	-

	S	CD	PJO	M	K	Total
pH group						
3.1 - 3.5			0.3			0.3
3.6 - 4.0		0	0.3	0.5		0.3
4.1 - 4.5	4.5	0.5	1.3	4.4		2.1
4.6 - 5.0	0	0	1.5		3.5	1.1
5.1 - 5.5	3.0	4.5			4.0	4.0
5.6 - 6.0					0	0

	S	CD	PJO	M	K	Total
L. o. I.						
0 - 19%	3.0	1.5	0		2.9	2.2
20 - 39	3.0	0.4	1.2			1.3
40 - 59			0.3	0		0.3
60 - 79			0.1	0		0.1
80 - 99			0.9	2.7		1.2

	S	CD	PJO	M	K	Total
Soil depth						
1 - 3	0	0.6	1.0			0.7
4 - 6	3.0	1.6	0.9	12.0	5.8	1.9
7 - 9	0	0	0	1.3	0	0.2
10 - 12	9.0		0.5	1.6	0	2.3
13 - 18			1.0			1.0
over 19			0.3			0.3

In Germany (Grebe 1918) this moss grows on raw humus soils, and in Scotland (Fraser 1940) on dry heaths. Watson (1955) avers that it inhabits a wide range of soil type, but always grows amongst other plants. Here it does best on the screes, the two poorly drained gleys, K and M, and the dry brown forest soil. It is low on the podzols and absent from soil type L.

In soil reaction it appears on even the lowest groups but returns higher frequencies above pH 4.0.

Rhytidiadelphus triquetrus

Soil type	Total Frequency	Average Frequency
C	7	1.4
S	1	0.3
L	1	0.3

pH group	SCL	L. o. I.	SCL	Soil depth	SCL
4.6 - 5.0	0.8	0 - 19%	1.3	4 - 6	1.2
5.1 - 5.5	1.3	20 - 39	0.9	7 - 9	3.0
5.6 - 6.0	1.0	40 - 59	0	10 - 12	0.3

This moss which is most frequently met in woods or forests over calcareous clays in England (Watson 1955) and raw humus soils in Germany (Grebe 1918) has been found in Ireland to be absent from woodland soils without a mor covering to the mineral horizons (Gorham 1954). Its pH range in America is given by Montgomery (1931) as 6.6 to 7.2.

It is here present on the grassy vegetation of freely drained brown forest soils and as traces from the screes and the wettest gley. There is a positive correlation with soil reaction above pH 4.6 - 5.0 (see fig. 34).

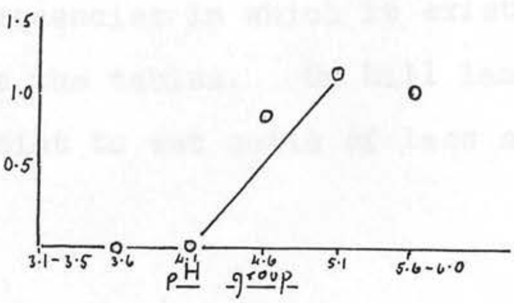


Fig 34.

Mnium hornum

Soil type	Total Frequency	Average Frequency
L	3	0.8
M	2	0.2
D	1	0.2
K	1	0.1
J	1	0.04

pH group	DJMKL	L. o. I.	DJMKL	Soil depth	DJMKL
3.1 - 3.5	0	0 - 19%	0.1	1 - 3	0
3.6 - 4.0	0.05	20 - 39	0.7	4 - 6	0.1
4.1 - 4.5	0.1	40 - 59	0.3	7 - 9	0.2
4.6 - 5.0	0.1	60 - 79	0	10 - 12	0.2
5.1 - 5.5	0	80 - 99	0.1		
5.6 - 6.0	1.3				

This moss has been recorded by Balme (1953) from freely drained rendzinas, brown forest soils and incipient podzols in low frequencies and by Mitchell and Jarvis (1956) from brown forest soils and podzolic gleys. Montgomery (1931) records it only from the pH range 7.0 to 7.4 in America, but Balme (1953) found it between 4.2 and 7.5. Gorham (1954) found it indifferent to soil depth but here it grows only on soils over 4 inches deep.

The low frequencies in which it exists make it difficult to use the tables. On hill land it appears to grow on the moist to wet soils of less acid soil reaction.

Mnium undulatum

Soil type	Total Frequency	Average Frequency
O	1	0.3
L	1	0.3
K	1	0.1
J	3	0.1
M	1	0.1

pH group		L. o. I.		Soil depth	
3.1 - 3.5	0.7	0 - 19%	0.1	1 - 3	0
3.6 - 4.0	0.1	20 - 39	0.3	4 - 6	0.1
4.1 - 4.5	0.1	40 - 59		7 - 9	0.1
4.6 - 5.0	0.3	60 - 79	0.2	10 - 12	0.1
5.1 - 5.5	0.2	80 - 99	0.1	13 - 18	1.0
5.6 - 6.0	0			over 19	0

Although found in very low frequencies this moss has returned records from most groups of pH, loss on ignition and soil depth. The only common feature of the soils it grows on is that they are wet.

Plagiothecium undulatum

Soil type	Total Frequency	Average Frequency
M	7	0.8
J	13	0.5
O	1	0.3
P	1	0.06

pH group	PJOM	L. o. I.		Soil depth	
3.1 - 3.5	0.7	0 - 19%	1.0	1 - 3	0.3
3.6 - 4.0	0.1	20 - 39	0.3	4 - 6	0.2
4.1 - 4.5	0.6	40 - 59	0.5	7 - 9	0.2
4.6 - 5.0	2.5	60 - 79	0.1	10 - 12	1.4
		80 - 99	0.4	13 - 18	0
				over 19	0.3

This is regarded as a moss of wet moors and upland oakwoods in Britain (Watson 1955) and of forest soils in Germany (Grebe 1918). Mitchell and Jarvis (1956) include it in their lists for podzolic soils, peat and non-calcareous gleys. The average frequencies are here very low but they are all in the podzolic group of soils. The two moist to wet soils, J and M, are more likely to bear it than the peat O or the relatively dry soil P. The range of factors which it spans are those of the podzolic soils and probably in no way reflects the plant's tolerances.

Leucobryum glaucum

Soil type	Total Frequency	Average Frequency
J	7	0.3
P	2	0.1

pH group	PJ	L. o. I.	PJ	Soil depth	PJ
3.1 - 3.5	0	0 - 19%	0	1 - 3	0
3.6 - 4.0	0.3	20 - 39	0	4 - 6	0.3
4.1 - 4.5	0.1	40 - 59	0	7 - 9	0.1
4.6 - 5.0	0	60 - 79	0.6	10 - 12	0.5
		80 - 99	0.1		

This inhabitant of woodlands and moorlands is always found on wet acid soil (Watson 1955). Nothing in the tables contradicts this statement and it should be added that the moss is confined to peats with a high organic matter content none less than 4 inches deep.

Sphagnum spp.

Soil type	Total Frequency	Average Frequency
O	12	3.0
M	6	0.7
J	2	0.1

	J	O	M	JOM
pH group				
3.1 - 3.5	0	1.0		0.7
3.6 - 4.0	0	5.0	0	0.5
4.1 - 4.5	0.2		1.2	0.5
4.6 - 5.0	0			0
L. o. I.				
0 - 19%	0			0
20 - 39	0			0
40 - 59	0		0	0
60 - 79	0.2		0	0.2
80 - 99	0	3.0	0.8	0.7
Soil depth				
1 - 3	0			0
4 - 6	0		0	0
7 - 9	0		0	0
10 - 12	1.0		1.2	1.1
13 - 18		1.0		1.0
over 19		3.7		3.7

These mosses are associated always with bog formation. They are among the principal peat-forming plants of the British Isles. Many accounts of bogs have been given but all agree that the substrate is almost always a deep wet peat, very low in acidity and very high in organic matter content, (Smith 1904, Rankin 1919, Fraser 1933, Ostwald Tansley 1939, Pearsall 1938).

It is not an abundant plant in the partly drained mosses of the eastern Lammermuirs and only dominant in local hollows in the peat. Its greatest frequency is, as would be expected, in soil O and smaller figures are returned from the two wet podzolic soils. The table shows the peat to be deep and high in loss on ignition and the pH range to be low.

Group 6: Species recorded from three or fewer sites and in very low frequencies

Forty plants were recorded in figures that allow of no real assessment of their relationships with the soils. Some few are hill plants of rare or local distribution, many are lowland plants at the limits of their ranges and some are agricultural grasses and weeds brought in by the sheep or in their food. They are given here along with the soil types and the soil factor groups in which they occur, without further comment.

		Range of soil factors		
Species	Soil type	pH	L.o.I.%	Depth in.
Nasturtium officinale	K	5.1 - 5.5	0 - 19	7 - 9
	L	5.1 - 5.5	80 - 99	10 - 12
Helianthemum chamaecystus	S	4.1 - 5.5	0 - 39	4 - 12
	C	5.1 - 5.5	0 - 19	4 - 6
Urtica dioica	D	4.1 - 4.5	0 - 19	1 - 3
	K	5.6 - 6.0	0 - 19	7 - 9
Veronica chamaedrys	D	4.6 - 5.0	0 - 19	1 - 3
	K	5.1 - 6.0	0 - 19	4 - 9
Ajuga reptans	S	4.6 - 5.0	20 - 39	1 - 3
	D	4.1 - 4.5	0 - 19	1 - 3

Species	Soil type	Range of soil factors: pH	L.o.I.%	Depth in.
Poa annua	C	4.6 - 5.0	20 - 39	4 - 6
	D	5.1 - 5.5	0 - 19	1 - 3
Cynosurus cristatus	D	5.1 - 5.5	0 - 19	1 - 3
	K	5.1 - 5.5	0 - 19	7 - 9

Group 7: Plants recorded from one soil only

Species	Soil type	Range of soil factors: pH	L.o.I.%	Depth in.
Primula vulgaris	S	4.6 - 5.0	20 - 39	1 - 3
Digitalis purpurea	S	4.6 - 5.0	20 - 39	1 - 3
Senecio sylvaticum	S	4.6 - 5.0	20 - 39	1 - 3
Hypochoeris radicata	S	4.1 - 4.5	0 - 19	10 - 12
Crepis capillaris	S	4.1 - 4.5	0 - 19	4 - 6
Lathyrus montana	S	5.1 - 5.5	0 - 19	10 - 12
Juniperus communis	C	3.6 - 4.0	20 - 39	1 - 3
Chamaenerion angustifolium	C	4.1 - 4.5	0 - 19	4 - 6
Lotus corniculatus	C	4.6 - 5.5	0 - 39	1 - 3

Species	Soil type	Range of soil factors pH	L.o.I.%	Depth in.
Polygala serpyllifolia	D	4.1 - 4.5	0 - 19	1 - 3
Vicia sepium	D	4.1 - 4.5	0 - 19	1 - 3
Fragaria vesca	D	4.6 - 5.0	0 - 19	1 - 3
Geum urbanum	D	4.1 - 4.5	0 - 19	1 - 3
Senecio jacobea	D	4.1 - 4.5	0 - 19	1 - 3
Cirsium arvense	D	4.1 - 4.5	0 - 19	1 - 3
Dactylis glomerata	D	4.1 - 4.5	0 - 19	1 - 3
Arrhenatherum elatius	D	4.1 - 4.5	0 - 19	1 - 3
Thelypteris dryopteris	D	4.1 - 4.5	0 - 19	1 - 3
Galium verum	D	4.1 - 4.5	0 - 19	1 - 3
Galium cruciata	D	4.1 - 4.5	0 - 19	1 - 3
Genista anglica	P	4.1 - 4.5	20 - 39	4 - 6
Rhytidiadelphus loreus	O	3.6 - 4.0	80 - 99	Over 19
Cerastium vulgatum	K	5.6 - 6.0	0 - 19	7 - 9
Sagina nodosa	K	5.6 - 6.0	0 - 19	7 - 9
Carex ovalis	K	5.6 - 6.0	0 - 19	7 - 9
Carex pulicaris	K	5.1 - 5.5	0 - 19	7 - 9

Species	Soil type	Range of soil factors		
		pH	L.o.I.%	Depth in.
Carex vesicaria	K	5.1 - 5.5	0 - 19	4 - 9
Festuca pratensis	K	5.1 - 6.0	0 - 19	4 - 9
Poa trivialis	K	5.1 - 6.0	0 - 19	7 - 9
Helictotrichon pubescens	K	5.1 - 5.5	0 - 19	7 - 9
Lathyrus pratensis	K	5.1 - 5.5	0 - 19	4 - 9
Brachythecium purum	K	5.1 - 5.5	0 - 19	4 - 6
Prunella vulgaris	L	5.5 - 6.0	20 - 39	7 - 9

Chapter XII

DISCUSSION

A soil type is characterised not only by the morphology of its horizons but also by biological and chemical features. The range of variation of several characteristics of the soils reported on here is shown in table 42, p.196, and illustrated in Diagram VII, p. 198. Knowing the limits of these variations for a number of soil types and of the behaviour of different plant species on them, it is possible to deduce approximately the probable tolerance of these plants to individual pedological factors in the field.

In attempting to use the information collected in this account for this purpose it has been found convenient to list the species according to their preferences for the various soil types. The major soil groups form a convenient frame for this classification. The soils within a group are sufficiently alike, yet so distinctively different from those of any other group, in single factors such as acidity, (see Diagram VII), that they can be considered together. The groups which appear in this study are, brown forest soils of low base status, podzolic soils and non-calcareous gleys.

In compiling the lists, the criteria for inclusion of any species in a particular group were not fixed rigidly. The general trends of the average frequencies of each species upon the various soil types were considered and then it was referred to the soil group in which it was found to have attained its greatest development.

Plants characteristic of the brown forest soils:

Ajuga reptans	Lotus corniculatus
Campanula rotundifolia	Oxalis acetosella
Helianthemum chamaecystis	Poa annua
Holcus mollis	Pteridium aquilinum

Thymus drucei

These are species of the moderately acid, moder or mineral soils in which the drainage is good: in the Lammermuirs they are all grassland or woodland plants.

Plants of the podzolic soils:

Calluna vulgaris	Molinia caerulea
Erica tetralix	Trichophorum caespitosum
Eriophorum angustifolium	Plagiothecium undulatum
E. vaginatum	Leucobryum glaucum
Juncus squarrosus	Sphagnum spp.

These species may be said to prefer soils which are very acid and with a high organic matter content: little can be said about their relationships with drainage or depth of soil.

Plants of the non-calcareous gleys:

Agrostis stolonifera	Juncus articulatus
Cardamine pratensis	Juncus communis

Cirsium palustre *Nasturtium officinale*

Deschampsia caespitosum *Ranunculus repens*

These soils provide a medium which, in reaction, is neutral or slightly acid, poor in drainage and variable as to the topsoil, both in depth and organic matter content. The plants are nearly all confined to damp places and most to the less acid places.

Plants common to both brown forest and podzolic soils:

Empetrum nigrum *Hypnum cupressiforme*

Dicranum scoparium *Polytrichum juniperinum*

Plants common to brown forest soils and non-calcareous gleys:

Achillea millefolium	*Rumex acetosa*
Agrostis canina	*Trifolium repens*
A. tenuis	*Veronica chamaedrys*
Cynosurus cristatus	*V. officinalis*
Holcus lanatus	*Viola riviniana*
Plantago lanceolata	*Mnium hornum*
Poa pratensis	*Pleurozium schreberi*
Ranunculus acris	*Rhytidiadelphus squarrosus*
	R. triquetrus

The species listed above show a preference for moderately acid to neutral soils with a moder humus.

Plants common to podzolic soils and non-calcareous gleys:

Carex nigra *Mnium undulatum*

Polytrichum commune

The three plants show a wide degree of tolerance to the reaction of the soil and the type of humus: they usually prefer moist soils.

Plants common to all soil groups:

<u>Anthoxanthum odoratum</u>	<u>Luzula campestris</u>
<u>Deschampsia flexuosa</u>	<u>Nardus stricta</u>
<u>Festuca ovina</u>	<u>Potentilla erecta</u>
<u>Galium hercynicum</u>	<u>Vaccinium myrtillus</u>

<u>Hylocomium splendens</u>

These species enter into almost every plant community although sometimes in low frequencies. Usually they are prominent constituents of the vegetation and three, <u>Anthoxanthum</u>, <u>Galium</u> and <u>Potentilla</u>, have been recorded as abundant. Four species, <u>Deschampsia</u>, <u>Festuca</u>, <u>Nardus</u> and <u>Vaccinium</u> have been found as dominants or co-dominants on brown forest or podzolic soils.

It must be admitted that these lists can give only a very rough indication of the range of soil factors tolerated by any plant species. The value of the lists lies most in their use during a primary survey, when they act as indicators of the type of soil. A more accurate, but still only approximate, estimate of the properties of a species can be had from study of its distribution on the individual soil profile types rather than on major soil groups.

Table 53. The average frequencies of ten species on the full range of soil types

Species	Soil types S	C	D	P	J	O	M	K	L
Campanula rotundifolia	0.8	0.4	0.8	-	-	-	-	-	-
Erica cinerea	3.8	-	0.2	0.6	0.04	-	-	-	-
Erica tetralix	-	-	-	0.2	0.9	1.5	-	-	-
Leucobryum glaucum	-	-	-	0.1	0.3	-	-	-	-
Galium hercynicum	4.5	5.8	11.5	0.8	2.3	-	4.1	6.5	8.8
Mnium undulatum	-	-	-	-	0.1	0.3	0.1	0.1	0.3
Deschampsia caespitosa	-	-	-	-	-	-	0.1	0.3	-
Agrostis stolonifera	-	-	-	-	-	-	-	4.4	4.5
Ranunculus repens	-	-	-	-	-	-	-	3.8	4.8
Cardamine pratensis	-	-	-	-	-	-	-	0.8	2.5

From Table 53 it is possible, in the case of each species, to estimate something of its tolerance of the factors which have been measured. In cases such as this, the absence of a species from any particular soil type provides evidence as valuable as its average frequency on others. For instance, note Campanula rotundifolia, which is present on soils S, C and D. Its absence from soils O, K and L suggests that it is probably intolerant of extreme wetness of the soil.

Again its absence from the podzolic soils indicates intolerance of much acidity. This plant's preference, in the Lammermuirs, would seem to be for the drier moder or mineral soils with a "moderate" acidity, that is, a pH between 4.0 and 5.0. Erica cinerea is also a plant of dry places but can exist in both mor and moder soils. On the other hand Erica tetralix shows a preference for the deep acid peats of the wettest podzolic soils. Similarly Leucobryum glaucum is confined to acid mor soils but it shuns the peat of soil "O".

Galium hercynicum is almost ubiquitous in the area surveyed but attains its highest average frequencies on moder soils of moderately acid or neutral soil reaction. As the trend of its frequency within each major soil group is to rise as the drainage becomes poorer this plant probably finds moist to wet soils more congenial than dry ones.

Mnium undulatum is found only on wet soils and is probably tolerant of both humus types and a wide range of soil acidity. Deschampsia caespitosa is restricted to poorly drained soils. Agrostis stolonifera and Ranunculus repens grow only on the two non-calcareous gleys, which suggests a preference for the highest range of soil reaction which can be found in this hill area and an intolerance of dry or mor soils. Cardamine pratensis finds the very wet and near neutral soils a more congenial habitat than those which are dry or acid or contain mor humus.

Although the state of the soil moisture has not been measured as have acidity and loss on ignition, it is still possible to make an assessment of drainage conditions from the morphology of the soil profile. The state of the drainage and its effect on the soil is the basis on which the soils have been classified. Each drainage class is an indication of the action of telluric water on the soil over a period of time and not a measure of the proportions of water to solid material at a particular time.

It is a matter of considerable ecological interest to know how plants react to a range of moisture conditions when expressed in this way. Few plants are indifferent to the state of the soil moisture and many are very sensitive to vagaries in this feature. Therefore, they can be more exact indicators of conditions in the habitat in respect of this feature than in others such as soil reaction. A classification of the species on the basis of their association with particular drainage conditions has been made. There are five groups, comprising plants of dry soils, plants of dry to moist soils, plants of moist to wet soils, plants of wet soils and those widely tolerant.

Plants of dry soils:

<u>Campanula rotundifolia</u>   <u>Teucrium scorodonia</u>

Erica cinerea	Thymus drucei
Oxalis acetosella	Polytrichum juniperinum

Plants of dry to moist soils:

Pteridium aquilinum	Plantago lanceolata
Agrostis tenuis	Veronica officinalis
Empetrum nigrum	Viola riviniana
Festuca ovina	Rhytidiadelphus squarrosus
Holcus mollis	Pleurozium schreberi
Nardus stricta	Leucobryum glaucum

Plants of moist to wet soils:

Agrostis stolonifera	Poa pratensis
Deschampsia caespitosa	Ranunculus acris
Holcus lanatus	Trichophorum caespitosum
Juncus squarrosus	Trifolium repens
Molinia coerulea	Mnium hornum
	Polytrichum commune

Plants of wet soils:

Cardamine pratensis	Juncus articulatus
Cirsium palustre	Juncus communis
Erica tetralix	Ranunculus repens
Eriophorum vaginatum	Mnium undulatum
E. angustifolium	Sphagnum spp.

Plants growing in a wide range of drainage conditions:

Anthoxanthum odoratum	Galium hercynicum
Calluna vulgaris	Luzula campestris
Deschampsia flexuosa	Potentilla erecta
Festuca ovina	Vaccinium myrtillus

These last species are not wholly indifferent to the moisture in the soil. Anthoxanthum, for instance, returns higher average frequencies from moist and wet soils than from dry ones and Festuca ovina is more abundant on moist soils than on either dry or wet ones.

Deduction from the behaviour of a plant on a range of soils can only furnish an approximate guide to its ecological characteristics. Had a larger number of individual factors been measured for each soil type there would be a greater possibility of obtaining a most detailed assessment. A more accurate picture of the responses of the plants to these individual soil factors can be had from the simultaneous collection of data on the species and the soil factors in question. The results of such a survey have been presented in Chapter XI where the relationships of each species to soil type and soil factors have been discussed. It remains here only to treat of a few general points.

The information provided in the accounts of the various species allows one to classify the plants on the basis of their responses to the soil factors. Such a classification can be but approximate and subject to overlapping of the groups. Nevertheless it is a useful way of systematising knowledge of the ecology of the plants involved. From the classes lists of what may be described as "indicator" species may be compiled. It is not necessary for a plant to be included in a group that it be restricted to that group. The criterion used in separating the species has been the trend shown by the average frequencies over several situations. The plant is included in that group in which it attains its greatest abundance.

With regard to soil reaction the classification evolved here differs from that of Small (1954) who dealt with the whole range of the tolerance of a species as recorded over a number of widely spread areas and from that of Pearsall (1952) who considered plant communities in relation to a number of soil conditions including soil acidity. This is because the species are here considered individually and within the rather narrow limits of a restricted area. The groups do resemble those suggested by Pearsall, probably for the reason that his findings were the result of study of localities similar to the one which formed the subject of this account.

The species treated of here are placed according to whether their highest average frequencies occur in sites having values which are (1) below pH 4.0, corresponding to Pearsall's Class I and Small's acidiphilous group; (2) between pH 4.0 and pH 5.0, corresponding to Pearsall's Class II and in part to Small's acid-tolerant and amphitolerant groups; or (3) above pH 5.0, usually rising towards pH 6.0, corresponding to Pearsall's Classes III and IV and Small's amphitolerant and mesophilous groups.

Group 1: Plants associated with soils having pH values below pH 4.0

Calluna vulgaris	Erica tetralix
Carex nigra	Trichophorum caespitosum
Eriophorum vaginatum	E. angustifolium

These plants are almost wholly confined to this group. All except E. angustifolium play a prominent part in communities developed over very acid soils probably because few species are tolerant of such conditions. They are commonly regarded as typical moorland plants.

Group 2: Plants associated with soils having pH values between pH 4.0 and pH 5.0

Agrostis tenuis	A. canina
Deschampsia flexuosa	Holcus mollis
Molinia caerulea	Nardus stricta
Campanula rotundifolia	Erica cinerea
Empetrum nigrum	Galium hercynicum
Juncus squarrosus	Luzula campestris
Oxalis acetosella	Potentilla erecta
Vaccinium myrtillus	Viola riviniana
Dicranum scoparium	Hypnum cupressiforme
Mnium hornum	M. undulatum
Plagiothecium undulatum	Pleurozium schreberi
Polytrichum commune	

Some of the species belonging to this group are tolerant of the whole range of soil acidity values recorded from the area studied, but in all the maximum average frequency appears between the figures pH 4.0 and pH 5.0. Among them are the most widespread plants found there: those, like Potentilla erecta, which are found on almost every soil type and in nearly every plant community.

Group 3: Plants preferring soils having pH values above pH 5.0

Agrostis stolonifera	Anthoxanthum odoratum
Deschampsia caespitosa	Holcus lanatus
Poa pratensis	Achillea millefolium
Cardamine pratensis	Cirsium palustre
Juncus articulatus	Plantago lanceolata
Ranunculus repens	Teucrium scorodonia
Thymus drucei	Trifolium repens
Veronica officinalis	
Rhytidiadelphus squarrosus	R. triquetrus

The full range of acidity values tolerated by many of the species in this group is not normally found in upland soils. Only soils with values at the lower end of the range have been recorded by the survey. Most of the plants are associated with lowland soils which have generally higher pH values. They are capable of growing in the uplands only on the limited number of sites in which the soil reaction is suitable and usually record an increase in average frequency as the soils on which they grow show a decrease in acidity.

In considering the proportions of organic matter to mineral matter in the soil in relation to the plants growing on them two distinct classes emerge. There are those species characteristic of soils with a low value for loss on ignition and those characteristic of soils with a high value. The former soils are roughly equivalent to those with a moder topsoil and the latter of those with mor topsoils, but containing also the sedge-peats which however occur in so few sites that they make an insignificant contribution to the data.

The group of plants growing on "mineral" soils include the following:

Achillea millefolium	Juncus articulatus
Agrostis canina	Luzula campestris
A. tenuis	Oxalis acetosella
Anthoxanthum odoratum	Plantago lanceolata
Campanula rotundifolia	Ranunculus acris
Cardamine pratensis	Teucrium scorodonia
Deschampsia caespitosa	Thymus drucei
Erica cinerea	Trifolium repens
Festuca ovina	Veronica officinalis
Holcus lanatus	Rhytidiadelphus squarrosus
H. mollis	R. triquetrus
	Pteridium aquilinum

The species which flourish on "organic" soils are:

Calluna vulgaris	Eriophorum vaginatum

Vaccinium myrtillus	*E. angustifolium*
Juncus squarrosus	*Molinia caerulea*
Trichophorum caespitosum	*Leucobryum glaucum*
	Sphagnum spp.

A number of plants are indifferent to this particular factor:

Agrostis stolonifera	*Poa trivialis*
Cirsium palustre	*Potentilla erecta*
Deschampsia flexuosa	*Ranunculus repens*
Empetrum nigrum	*Hypnum cupressiforme*
Erica tetralix	*Hylocomium splendens*
Juncus communis	*Polytrichum juniperinum*

The plants of the "organic" group are most frequent on heaths and moorlands while those of the "mineral" and "indifferent" groups are amongst the common components of grasslands and screes.

Most of the species dealt with are indifferent to the depth of the topsoils in which they grow. A small number do seem to be associated with shallow or deep soils:

Achillea millefolium	*Oxalis acetosella*
Agrostis tenuis	*Potentilla erecta*
Erica cinerea	*Ranunculus acris*
Holcus mollis	*Viola riviniana*

The above list of species forms a group in which each develops best on the shallow soils. Deeper soils are preferred by the following plants:

Calluna vulgaris	Agrostis stolonifera
Eriophorum vaginatum	Cirsium palustre
E. angustifolium	Holcus lanatus
	Plantago lanceolata
	Trifolium repens

The plants on the left hand side are those of deep peat, while those in the right hand column prefer mineral soils or are indifferent to type of organic matter.

Some species which grow on a wide range of soil types react in one way to increasing depth and variations in the organic matter content of the topsoil, on brown forest and gley soils, and in another way on podzols. When growing on the former they achieve their highest average frequencies on the deeper soils and those with a loss on ignition of 20 to 39% and their lowest on the shallow soils and those with loss on ignition values below 19%. On the other hand, when growing on podzols they prefer those soils which are shallow and have loss on ignition values of 0 - 19% rather than those which are deep and have organic matter contents of over 20%. Among the plants which behave in this way are those in the following list:

Anthoxanthum odoratum	Holcus mollis
Festuca ovina	Potentilla erecta
Galium hercynicum	

The explanation for this may be that these are truly "moder" plants with a preference for deep soils. In brown forest soils a high organic matter content and a deeper top layer allows them to develop to a greater extent. On the other hand, on "mor" soils the deeper turf of undecomposed fibrous organic matter makes it more difficult for the roots to penetrate to the mineral layer below and hence hinders the establishment and spread of the plants.

The classification of plant communities

One possible application of this work may be in the solution of a problem presently confronting ecologists who are concerned with the infinite variety of communities present in Calluna-dominated moorlands or hill grasslands. The classifications available at present are usually based on the floristic composition of the various plant communities, using Domin's scale, as recommended by Poore (1955a). As there are an infinite number of possible proportions in which the constituent species may be found the search is at present concentrated on the discovery of constant species, often of low frequency, by which communities apparently different may be related to one another. Difficulty is encountered in relating the units of vegetation to the factors which cause variation (King, oral communication).

In the map survey which was described in Section 1, several distinct types of plant community were recognised by fixing the limits of variation in species content for each type. It was found that a definite relationship existed between these vegetation types and soil profile types and suggested that the plant communities were dependent for their existence on the type of soil occupying the area. The relationships discovered by the first survey were confirmed in the second which also showed that the species responded both to the soil type and to changes in individual soil factors.

It will be fruitful to approach the problem of the interrelations of floristically different plant communities from a point of view which considers the soil the most important causal factor in their variability. In Table 54 p.360 are set out the average frequencies of nine important species of Calluna moor on the podzolic soils. If the figures given for the species on each soil type are regarded not as absolute values but as indications of the plant's relative abilities for development on that soil type, then it can be said that a column in the table is a pattern for the vegetation type growing on a particular soil type and that other types growing on that soil are variations due to differences in a particular soil factor or in climate or in biotic influences or in a combination of these.

The basic list for the podzol "P" shows that

Calluna is the major species and of the others only Nardus and Vaccinium myrtillus contribute appreciably to the vegetation. Soil "J", the podzol with the gleyed A_2 layer, carries less Calluna and a number of other species, including Molinia, Nardus, Vaccinium myrtillus, Juncus squarrosus, Trichophorum caespitosum, play a larger part in the communities. In the podzolic gley, "M", Molinia, Calluna and Juncus squarrosus are of equal importance and Nardus and Vaccinium myrtillus are subsidiary plants. Peat is the domain of Calluna and Eriophorum vaginatum.

Table 54. The average frequencies of nine moorland plants on four podzolic soils

Species	Soil type			
	P	J	M	O
Calluna vulgaris	18.6	12.4	8.0	16.5
Erica cinerea	0.6	0.04	-	-
Nardus stricta	4.2	6.6	3.0	-
Vaccinium myrtillus	3.9	6.1	3.0	4.5
Molinia caerulea	1.5	7.3	8.4	1.5
Juncus squarrosus	0.8	3.4	7.0	2.3
Trichophorum caespitosum	0.9	2.4	1.7	1.3
Erica tetralix	0.2	0.9	-	1.5
Eriophorum vaginatum	-	0.8	1.8	14.3

In hill grassland the picture arising is similar, of a sward varying in accordance with the soil type of its substrate (Table 55, p. 362). The four species, Molinia, D. flexuosa, Nardus and Festuca ovina are most likely to contribute to a sward upon the podzolic soils. All four are present on soil J, Molinia is absent from soil P, Nardus is lowest and Deschampsia flexuosa highest in soil M, and only Molinia and D. flexuosa could contribute to a sward on peat.

On the moder soils, which are more usually associated with grassland, the screes bear D. flexuosa, Agrostis tenuis and F. ovina. The dry brown forest soil has D. flexuosa and F. ovina followed by Nardus and a group composed of A. canina, A. tenuis, Anthoxanthum and Holcus mollis.

On the moist brown forest soil, "D", two species, Agrostis tenuis and Festuca ovina form the bulk of the sward with Anthoxanthum, and, in lesser amounts, Holcus lanatus, D. flexuosa and A. canina. The poorly drained gley soil, "K", has a high value for F. ovina and a group composed of Anthoxanthum, Nardus stricta and A. tenuis with H. lanatus, A. stolonifera and A. canina in lesser amounts. Soil "L", the very poorly drained gley soil bears a sward of Agrostis tenuis, Anthoxanthum and Holcus lanatus with F. ovina and A. stolonifera.

Comparison of these lists with those given in Section 1 shows the validity of the soil-vegetation

Table 55. The average frequencies of ten grassland species on all soil types

Species	L	K	D	C	S	O	J	M	P
Molinia caerulea	—	—	—	—	—	1.5	7.3	8.4	0.6
Deschampsia flexuosa	-	1.5	2.7	6.4	7.5	1.3	6.3	10.9	5.3
Nardus stricta	2.0	9.3	1.5	4.2	0.3	-	6.6	3.0	4.2
Agrostis tenuis	9.3	9.0	12.8	2.8	8.0	-	1.0	1.3	0.8
Anthoxanthum	9.0	9.3	6.0	3.6	2.3	0.3	2.4	0.8	0.6
Festuca ovina	7.8	13.5	11.7	8.8	5.8	-	5.9	8.3	5.5
Agrostis canina	5.0	4.4	2.0	3.8	-	-	1.5	0.6	0.4
Holcus mollis	0.3	0.1	0.5	3.0	-	—	—	—	—
Holcus lanatus	8.5	6.9	3.7	—	—	—	—	—	—
Agrostis stolonifera	4.5	4.4	—	—	—	—	—	—	—

units which have been established. The contention is that in the Lammermuir Hills the soil determines the limits within which the plant community may vary. Such variation within these limits is due to differences in individual soil factors, such as soil reaction or the levels of essential nutrients, or possibly to biotic and climatic influences.

The average frequency is a crude method to use for this particular purpose. It does not show up the range of variation in floristic content and it is not possible to examine the influence of dominant plants in modifying the habitat for constituent species. The method which suggests itself as suitable for this type of study is that of Poore (1955a), referred to earlier, but modified so that the floristic lists are first grouped on the basis of the various soils on which they were found growing. Next they may be subdivided on the basis of their floristic affinities. From this it should be possible to construct a basic series of soil-vegetation units and then to go on to discover the influences causing variation within them.

SUMMARY AND CONCLUSIONS OF SECTION 2

1. The methods used in conducting the survey are described.
2. In Chapter VIII, material is presented which confirms the findings of Section 1, that each plant community is associated with a particular soil type or group of soil types.
3. The values of acidity, loss on ignition, and depth of topsoil are given for each plant community.
4. The species content of the flora in relation to soil factors is examined. It is found that podzols are poorest and non-calcareous gleys richest in this respect. Neutral and mineral soils bear more species than acid or organic soils respectively.
5. Evidence is presented which shows the relationships of the distribution of each of fifty-four species in relation to soil type and three soil factors.
6. The discussion deals with some general points not touched upon in the accounts of the various species and puts forward the suggestion that soil-plant relationships may form one basis of a floristic classification of plant communities.

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